THE BLADE BLIGHT OF OATS
A BACTERIAL DISEASE

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Agricultural Experiment Station

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BULLETIN 210

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BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 210. OCTOBER, 1909.

THE BLADE BLIGHT OF OATS—A BACTERIAL DISEASE.

By THOS. F. MANNS.

INTRODUCTION.

During the past three seasons the oat crop of Ohio has sustained much loss from a blight disease which has been quite general throughout the Central and Eastern states. From the many inquiries by the farmers of Ohio, and the great differences of opinion among scientific workers, it is quite evident that the nature of the trouble has not been well understood. Many of the farmers supposed the trouble to be of the nature of a rust (See page 98). Among the scientific workers the conclusions reached were widely different. In one section insects[1] were noted as a cause; in another case,[2] while the origin of the trouble was held to be in doubt, its wide spead development was believed to be due the cold, wet, cloudy season. A third investigator found the disease not to be directly the result of insect work[3]. Prof. J. Dearness[4] writing through the Farmer's Advocate, a Canadian paper, in 1907, (after having reviewed the New York State Reports for 1889-1890 by C. H. Peck) supposed the cause to be either bacterial, in the class with the bacterium of pear blight, or else due to the reduction of the vitality of the oats through climatic causes. Prof. Selby, in a report on plant diseases,[5] supposed the trouble to be due to the great changes of weather, possibly aided by aphides. A similar trouble in 1890 was pronounced by the Division of Plant Pathology, Department of Agriculture, Washington, D. C., to be due to bacteria[6]. In Connecticut a similar disease was supposed to be

[1]Special Bulletin No. 38, Michigan Agricultural College, July 1907, R. H. Pettit.
[2]Press Bulletin No. 286, Ohio Experiment Station, July 15th, 1907, Chas. E. Thorne.
[3]Journal of Economic Entomology, June 1908, pp 190 and 191, H. A. Gossard.
[4]Farmer's Advocate, London, Ontario, Vol. XLII, No. 775, Aug. 1, 1907, Prof. J. Dearness.
[5]Ohio Agricultural Report, 1907, p. 891.
[6]Journal of Mycology, Vol. 6, pp. 72-3, 1890, B. T. Galloway and E. A. Southworth.

due to insects[7]. What appears to have been the same disease was prevalent in New York in 1889 and was pronounced by C. H. Peck[8] as due to a fungus; however, this view was later modified and Prof. Peck pronounced the disease not to be due to fungi, and he further noted that he believed it was not the results of insects or nematode work[9]. In 1906 the Connecticut Station reported an outbreak of a disease somewhat similar to the blight in which they could find no bacteria as an associated cause. "The trouble apparently resulted from unfavorable weather conditions, possibly aggravated by some root disease."[10] Insects many times in the past[11 12 13] have been assigned as causing blights of oats which appear very similar from descriptions to the severe blight of 1907-8.

CAUSE.

The author finds the disease, as manifested in Ohio, to be caused by a symbiotic relation of two species of bacteria; the disease being greatly influenced by weather conditions and to some extent disseminated by insects.

PREVIOUS LITERATURE ON THIS DISEASE

Very little has been previously written upon this disease, and where studies or notes have been reported the articles are very short; for these reasons the writer quotes very fully from the references noted. The disease as it appeared in 1890 was described by Galloway and Southworth as follows:[6]

"During the months of May and June, 1890, we received repeated complaints and inquiries concerning a mysterious oat disease which then threatened to destroy the entire crop of the Eastern and Central States.

During the month of May, when the oats were from 6 inches to a foot in height, the leaves suddenly began to turn brown and die at the tops. The lower leaves were attacked first and the brown color soon extended their entire length. In a very short time all the leaves were dead or partially brown, and the prospects were that the plants would die and the oat crop be a total failure. About the middle of June, however, the fields began to revive, the oats put out some few fresh, green leaves, most of them headed out, and by the first of July many of the fields appeared in a fair condition on superficial observation. In reality, however, the losses from the disease will amount to from 35 to 75 percent of the crop, according to the locality. Very discouraging losses are reported from the State of Pennsylvania, where there is probably not a healthy oat field to be found. Kentucky and Tennessee have suffered even more, their present averages as reported to the Statistical Division being the lowest ever reported from any state for a staple crop.

[7]13th Annual Report of Connecticut Agricultural Experiment Station, 1889, p. 180. Roland Thaxter.

[8]New York State Report, 1889.

[9]New York State Report, 1890.

[10]Report of the Connecticut Agricultural Experiment Station for the year 1906, Part V., p. 316.

[11]Insect Life, Vol. III, p. 306.

[12]Bulletin 108, Division of Entomology, Agric. Exp't. Sta., Minn., April 1908, F. L Washburn.

[13]Bulletin 44, United States Department of Agriculture, Division of Entomology, 1904.

[6]Journal of Mycology, Vol. 6, p. 72-3, 1890.

The disease extends from New England to Georgia, and from the Atlantic coast as far west as Indiana and Illinois. It is not present in Michigan. All the agents for the Statistical Division agree in ascribing the cause of this remarkable decline in the oat crop to the same thing, namely, a "blight" or "rust" which struck the fields in May.

The disease prevented the oats from stooling well, and it frequently happened that all the shoots but the main one of a stool were killed. As a result the oats are very thin, and in riding along by a field even at a considerable distance one can see to the ground between the drill rows when the oats are in full head. Besides this the losses are augmented by the fact that the amount of green foliage which developed after the attack, was not sufficient to produce a strong growth of the surviving stalks, nor to supply material for a good-sized head; the straw is therefore short and light and the heads small. The heads do not seem to be well filled, and threshing will probably reveal a lighter yield than farmers themselves expect.

Such a universal disease can be attributed to no deterioration of soil or lack of cultivation, although there is no doubt that good cultivation will produce better oats than poor, even when they are diseased. The disease has attacked oats on the best as well as on the poorest soils, fields that were fertilized as well as those that were not. The oats are best, however, in level well cultivated and drained fields, while they are poorest in low, wet spots and on hillsides and other places where the soil is thin. In such places they are too short to be harvested.

A very careful study of the plants has been made in the field and laboratory, but nothing in the way of a fungous or animal parasite that could cause the trouble has been found. From the nature of the disease our attention has been directed mainly to a study of it from a bacterial standpoint. Bacteria have been found in every specimen examined. Nearly 200 cultures have been made in at least a dozen different media and all have yielded two germs, one of which is exceedingly abundant. In nearly 50 cases the disease has been produced in young pot-grown plants by inoculating from direct material. Inoculations of young plants with pure cultures are now under way and it is hoped that some definite results will soon be obtained from this source.

(Since writing this the disease has been produced in fifty or more cases by inoculating with the more abundant organism. Five days after inoculating, the characteristic discolorations appeared and cultures made from these have yielded the typical organism in a nearly pure condition.)"

There is still a possibility that although the disease may be caused by bacteria they are dependent upon certain conditions of the atmosphere for their development, and need not be feared another year. Experiments to settle this question are also under way.

What appears to have been the same disease was described by Prof. C. H. Peck as occurring in New York in 1889 and the cause was attributed to a fungus, *Fusicladium destruens*. He reported as follows:[8]

"In the southern part of St. Lawrence County, which was visited by the writer the past summer (1889) scarcely a field of oats was free from this disease. So prevalent was it that the general color of the fields was changed thereby, and it was the opinion of the owners that their oats were rusting badly. Upon close examination, no rust was to be found. In its stead, the discoloration of the leaves and the fungus now described appeared. It is apparently a very injurious and destructive fungus."

[8]New York State Report 1889, C. H. Peck.

However, in 1890, Dr. Peck found upon further study of the disease, reason to modify his former conclusions in regard to Fusicladium being the cause. He reported as follows:[9]

"When my last report was written, this fungus (*Fusicladium destruens*) was suspected of being the cause of the disease, which has appeared over a wide extent of country, and in the fields examined scarcely an unaffected plant could be found. It is hardly possible that the Fusicladium could have spread so extensively in so short a time. It is more reasonable to suppose that it, like the other fungi mentioned, is a consequence rather than a cause of the disease." He noted, however, that the injury appeared not to be the work of insects or nematodes.

The Connecticut Station recognized the blight and reported as follows[7]:

"Coleothrips 3-fasciata Fitch: A 'rust' of oats has been the cause of much complaint throughout the State during the past summer, and where examined proved to be due, in most cases, not to the common fungus rusts (*Puccinia coronata and P. graminis*); but to a minute insect which Mr. Pergande, of Washington, has kindly determined as probably Coleothrips 3-fasciata Fitch. Fields infested by it have a reddish, wilted look and often mature comparatively little of their seed. No remedy can be suggested in this case."

Miss Freda Detmers, botanist of the Ohio Experiment Station for 1890 and '91, mentions a blight of oats due to bacteria upon which she did some work, quoted as follows:[14]

"The work of the division during the past year has mainly been confined to a careful study of the fungous diseases of plants. * * * * Briefly stated the diseases investigated are as follows:" Among many others is mentioned "an undescribed bacterial disease of oats."

Pettit described the trouble in March 1907 as follows[1]:

"From all parts of the state, complaints are coming in with respect to the condition of the oat crop. The last week has seen a notable change in the outlook. The young oats in a large part of the state have suddenly become as if stricken by blight, the outer leaves turning yellow and afterwards reddish until, after a little time, the field appears as if badly rusted. A closer examination shows that there are few if any rust pustules and the appearance on the surface is just enough different from that produced by rust to raise a doubt as to the real cause of the difficulty.

Careful examination with the aid of a powerful lens shows the culprit to be a minute insect called a thrips, very small, and very quick in its movements, jumping like a flea when disturbed and disappearing completely. These little creatures have narrow wings with fringes of long hairs instead of the ordinary form of wings. They scrape the surfaces of the oat leaves and cause them to become withered and to turn yellow and die. Now, this little creature has never been seen in numbers by the writer and it is very difficult to judge just what will be the outcome of the infestation. If one might judge by the behavior of its relatives one would expect the condition to improve after one or two good rains, since thrips, in general, thrive in hot, dry weather, and do not do well when it is moist. However, it seems to be quite serious in places where there has been a fairly good supply of rain. The larger the plants are, the better they fare.

[9]New York State Report, 1890.

[7]13th Annual Report Connecticut Agricultural Experiment Station, 1889, p. 180, Dr. Roland Thaxter.

[14]Ohio Experiment Station, in the Annual Report for 1891, p. XXXIV.

[1]Michigan Agricultural College, July 1907, Special Bulletin No. 38.

Now, there seems to be nothing one can do to check the trouble at this time. If it were possible to stimulate the growth of the plants in any way it would be a benefit, but such a course seems to be impossible. All plant life seems to be more susceptible to insects when plants are in poor condition for any reason, and the backward, cold, wet spring furnishes a very sufficient reason for the lack of vigor and resisting power which they should have to help repel the invaders."

Director Thorne, of the Ohio Station, reviews the disease[2] in a press bulletin as follows:

"Reports received by the Ohio Experiment Station indicate a general prevalence over the state of an abnormal condition of oats, shown by many of the blades turning yellow, or reddish yellow, in spots or streaks, and finally dying at the tips or throughout the entire length.

A similar condition was manifested by the oat crop of Ohio and farther west in 1890, followed by a considerable reduction in yield and such a condition is reported by the Connecticut Experiment Station as occuring in that state in 1906.

The attack of 1890 was pronounced by the Division of Vegetable Pathology, U. S. Department of Agriculture, to be due to bacterial infection. The Connecticut Station failed to find evidence of such infection last year, and we have not yet found conclusive evidence of such infection in the present attack.

In the case of the present attack plant lice have been mentioned by many observers as being unusually abundant on oats, but we have not as yet found conclusive evidence as to whether they have or have not, borne an important part in the spread of the trouble. We know of no remedy or prevention.

In all cases similar weather conditions have been observed, namely: excess of cold, rainy weather, followed by hot sunshine, and it appears that these conditions have been the chief factors in producing the outbreak.

In this connection the following extract from the report of this Station for 1890 (it being then located at Columbus) may be of interest:

'The Spring of 1890 was very unfavorable to farming operations throughout the greater portion of Ohio, on account of almost incessant rains. The planting of corn, oats and potatoes was generally delayed, and cultivation was much interferred with until after the middle of June. On the Station farm oats and potatoes were planted late, and both crops suffered so much from blight that not half an average yield was obtained.'"

Prof. H. A. Gossard in reviewing the insect troubles of 1907 writes as follows:[3]

"During the spring, wheat and oats over Ohio suffered from a peculiar disease, marked by a reddening, yellowing and browning of the leaves, and a general stunting of the growth and retardation of the development in all respects. From the fact that the grain louse, *Macrosiphum granaria*, was noticed in considerable numbers in some fields, the newspapers and many correspondents attributed the damage to the lice. Others suspected thrips of causing the mischief. After an examination which I deemed adequate, I concluded that neither of these insects was primarily responsible for the disease so far as Ohio was concerned, though both species added to the trouble to a

[2]Press Bulletin No. 286, Ohio Experiment Station, 1907.

[3]In the Journal of Economic Entomology "Notes of the Season" June 1908, pp. 190-191.

considerable degree in some fields. The majority of the diseased plants, however, were damaged but little by either insect, and many of them not at all, so far as I could determine. Corn, clover, alfalfa, strawberries and many weeds suffered in precisely the same way, as inferred from their external symptoms, and no insects whatever could be found upon them. I decided the trouble was probably wholly physiological in character, and was in all likelihood caused by the cold, wet spring. Parasites overtook the lice in most localities before they became excessively plentiful."

Prof. Selby in reviewing plant diseases in his report for 1907 says:[5]

"Oats showed a frightful collapse by leaf-blight when the season turned brighter; it seems to have been due to the sudden stress of the change (of weather), possibly aided at times by lice or aphides."

The same disease was evidently quite prevalent in Ontario in 1907. Prof. J. Dearness writing through the Farmer's Advocate[4] in answer to subscribers to that paper, after reviewing Dr. Peck's reports for New York, 1889-90, writes:

"I have examined the specimens of oats received from you, and labelled, respectively, from a correspondent in the county of Oxford; Mr. Twedle, county of Wentworth; Mr. Brodie, Middlesex; and from several other farms in the county of Middlesex.

The disease on all the specimens has similar characteristics. It appears as a blighting of the outer end of the leaf (but not usually of every leaf of the plant) and spreads along the veins towards the stem. As the tissues die, the color changes to a yellowish or reddish brown. I find no mark in root, joint, stem or leaf of the invariable presence of any insect. If the affection were due solely to adverse conditions of soil or weather, all the leaves, as well as the other parts of the plant, might be expected to be similarly discolored."

"His description (referring to Peck's N. Y. State reports) of the affected oat fields agrees exactly with those of your correspondents. The fungus he most strongly suspected at first is present on most of the leaves received here. If it is not the cause, but only a concomitant of the disease, then I should say that we have here either a destructive bacterium to be put in the class with the bacterium of pear blight, or a case of the reduction of the vitality of the oats, by some climatic cause, to such an extent as to permit the invasion of the fungi observed. The problem is an interesting and important one. It may already have been attacked and settled so far as the bacteriologist is concerned. If so, I have not heard the result."

Writing later he says:

"Since reporting to you on the specimens of blighted oat-leaves I have had the opportunity of visiting a number of fields. It may be said of all these that, in general, the stems, youngest leaves and panicles are not attacked by the blight.

In all the grass plants the regions of most vigorous growth are at the joints or just above them, while tissues at the leaf-tips, particularly of the older leaves, have the least vigor. The disease was limited to the latter regions of the oat plant.

I am of the opinion that the blight made no progress after a favorable condition of the weather set in, and that the changes in the color of the leaves and the invasion by fungi occurred and continued in areas of the leaves where the protoplasm had already lost its usefulness to the plant."

[5]Ohio Agricultural Report, 1907, p. 891.

[4]Farmer's Advocate, London, Ont., Vol. XLII, No. 775, Aug. 1, 1907.

The disease was noted in Canada in 1907 as follows:[15]

"Blighting of Oats: In addition to the above there was a rather wide-spread physiological blight reported during the summer. The trouble was mostly in oat fields and specimens showed the upper parts of the plants as yellowing and dying. Investigation failed to disclose any causative fungi present. The trouble was very probably due to unfavorable weather conditions, the root system having been impaired by a continued cold spell following an earlier warm season, the plants were unable to get proper nourishment and water supply from the ground."

What appears to have been an outbreak of a somewhat similar disease, though apparently not identical, has been described by G. P. Clinton[10] as follows:

"This trouble was first seen at Portland, the second week in June. During June and July it was noticed in almost all the oat fields examined, and so much have considerably reduced the yield. The leaves, especially the lower, became a sickly yellow, and many finally died prematurely. In some respects this trouble resembled the bacterial disease that occasionally occurs in the early summer in the oat fields of the West; but the leaves lacked the water-soaked appearance of that disease, and on examination failed to show any bacteria present. The trouble apparently resulted from unfavorable weather conditions, possibly aggravated by some root disease, though the few examinations made of the roots failed to show any suspicious fungus at work there. June and July had many heavy rain storms suddenly followed by bright hot days, and these sudden changes, as in other cases already mentioned, probably caused the injury. The same trouble was seen to a less degree on a number of other grasses, both wild and cultivated."

EXTRACTS FROM LETTERS—1907.

The large number of inquiries to Farm Journals and letters to the Experiment Station from farmers characterize the disease and emphasize its severity. The following extracts are typical:

"Fayetteville, Brown County, Ohio, 6-9-'07

Dear Sir:

There is something the matter with the oat crop here this season of which you can see by sample No. 2 sent you in this mail.

It looks very much as though some fields are gone entirely now. My oats were the earliest sown in this immediate vicinity and were the last to be attacked by this trouble, that is, a part of the field is turning red very rapidly. There are many of the green bug (aphis) in my field and I was wondering if they are the cause of all this. I am sending blades, both top and bottom and in all stages of color from beginning to end. What is wrong?

BERNARD QUINN."

"Ashtabula, Ashtabula County, Ohio, 6-14-'07.

Dear Sir:

I have been looking over my oats this afternoon and find they are looking much better. Enclosed please find sample of oats.

In travelling around this part of the country, I find the most of the oats are damaged similar to mine. The damage is all on the high ground.

C. J. METCALF."

[15]Report of the Ontario Agricultural College and Experimental Farm, Dept. of Botany, p. 49, 1907.
[10]Connecticut Agricultural Experiment Station Report 1906, Part V, pp. 316-17.

"Camden, Preble County, Ohio, 6-27-'07.

Dear Sirs:

I am sending under separate cover specimens of oats which I wish you would kindly examine. The oats in this entire country are affected with some disease which causes the leaves to turn brown beginning at the tips. Would you please let me know the nature of the trouble and what we may expect of this land if it is sowed in wheat the coming fall?

D. W. McQUEEN."

"LeRoy, Medina County, Ohio, 7-8-'07.

Dear Sir:

Will you please tell us the cause of the universal turning red and dying of the leaves on the oats, and what the probable result is going to be?

H. J. FREEMAN."

"Fredericktown, Ohio, 7-3-'07.

Gentlemen:

The oats through this county (Knox) is turning a reddish color of the blades, and seems to be dying.

I examined the roots and could distinguish nothing on the roots that I thought was an insect, excepting on one root.

C. F. BRADDOCK."

EXTRACTS FROM LETTERS 1908-9.

"Ansonia, Darke County, Ohio, 3-7-'09

Dear Sir:

I would like for you to send me a receipt for a dip to dip oats; when my oats get about six inches high it commences to get rusty, and don't grow thrifty, and when it heads it only about half fills the oats. It is all affected the same in this country.

F. J. FOLKERTH."

"Ansonia, Ohio, 3-23-'09.

Dear Sir:

What is it that is in the oats; is it a smut or does it come from the cold weather? The fields of oats get red as fire, that is, the blades. Is there anything that I could do for it?

R. D. FIELDS."

"Wainwright, Tuscarawas County, Ohio, 3-8-'09.

Dear Sir:

My oats are badly infested and yielded poorly the last two years.

GEO. SCHMITZ."

"Camden, Preble County, Ohio, 2-28-'09.

Dear Sir:

Would you kindly inform us as to the advisability of spraying or rather treating seed oats for blade blight?

We were badly infected with this two years since in Preble county.

DR. D. W. McQUEEN."

"Ashland, Ashland County, Ohio, 3-4-'09.

Dear Sir.

Kindly send me formula for treating rust in oats.

PALMER & DONLEY."

"Leipsic, Putnam County, Ohio, 12-28-'08.

Dear Sir:

We had exactly the same disease on our 1908 crop as we did on our 1907 crop, and I am thoroughly convinced if we had not ideal weather for oats crop, we would not have gotten scarcely anything.

I have given the subject very close attention for the last two years and I am thoroughly convinced that it is some disease on the oats and not climatic or weather conditions.

G. O. CRUIKSHANK."

"Fostoria, Seneca County, Ohio, 2-1-'09.

Dear Sir:

Will you please give me directions for treating seed oats that are affected with rust or what ever it is that has caused the oats to turn red before heading out? Oats in this vicinity have not yielded more than half a crop in the last two years, owing, as most farmers believe, to this trouble, although the last season was an exceptionally good one.

J. L. CRUIKSHANK."

"Shelby, Richland County, Ohio, 12-28-'08.

Dear Sir:

Will you please send me instructions how to treat oats for sowing to prevent blight?

R. C. WINBIGLER."

"Polk, Ashland County, Ohio, 1-11-'09.

Dear Sir:

Can the Station give me any information in regard to the condition of the oat crop of last year, which may be beneficial this year?

W. M. FELGER."

The following quotations, taken from the correspondence of Prof. A. D. Selby, Botanist and J. M. Van Hook, Assistant Botanist, in answer to queries in 1907, show many observations which throw much light on the oat blight disease.

"Wooster, Ohio, 6-18-'07.

Mr. C. J. Metcalf,

Ashtabula, Ohio.

Dear Sir:

This form of oat blighting has been quite common at the Station this year, especially on certain varieties, but is largely disappearing with better weather. It does not seem to be due to either insect or fungus, but to conditions surrounding the plant.

J. M. VAN HOOK."

"Wooster, Ohio, 6-28-'07.

Daniel C. Mayne,

Miamisburg, Montgomery County, O.

Dear Sir:

We have the same trouble with oats on the Station farm and have received specimens from many parts of the state. We believe this due to weather and resulting soil conditions more than anything else. There is more of it than I have ever seen before and many varieties on the plots here will be badly damaged even if it lets up at once. With the advent of continued warmer weather, I look for the trouble to diminish, though it made the disease worse at first. However, the green bug or louse, is appearing in numbers in many places and may do much damage unless we have clear warm weather.

J. M. VAN HOOK."

"Wooster, Ohio, 6-29-'07.

Mr. E. W. Falcott,
Kent, Portage County, O.
Dear Sir:

Your oat trouble is a general complaint this year. There were traces of it last year, but nothing like the present. On our variety plots it is very severe. Some varieties are worse than others and worse on high ground, as you say is true in your case. The yellowing of leaves up to this time, at least, seems largely due to bad weather, dark and cold. Increased by the sudden hot weather of the last two weeks.

J. M. VAN HOOK."

"Wooster, Ohio, 6-29-'07.

Mr. R. S. Shanks,
Ada, Hardin County, O.
Dear Sir:

This seems to be due not to any parasite but to bad conditions of weather. Evidently it has been aggravated very much by the recent change to hot, sunshiny weather, though such a change will doubtless be for the best as soon as the plants become adjusted to these conditions. In many cases the crop is considerably damaged already.

The green bug or plant louse is appearing and is damaging oats quite a good deal, but here on the Station farm parasites are developing rapidly and killing these bugs. Bright weather will do much to stop bug injury.

J. M. VAN HOOK."

"Wooster, Ohio, 7-2-'07.

Mr. W. M. Cook,
Canton, Stark County, O.
Dear Sir:

Your oats are attacked by aphides (lice) upon the leaves which puncture them and then these leaves subsequently turn red.

A. D. SELBY."

"Wooster, Ohio, 7-8-'07.

Mr. H. W. White,
Shiloh, Richland County, O.
Dear Sir:

At the beginning of the oat trouble there was a very great abundance of so called green bugs or aphides and the surface of the leaves appeared to have numerous punctures from them. Later with the finer weather the parasites killed off a large number of the lice, but there are still an abundance of leaves to break down, which in part lacks explanation. Latterly, however, the new leaves formed are all right and the shortage in the crop from the attack will probably not be excessive.

A. D. SELBY."

"Wooster, Ohio, 7-12-'07.

F. S. Aten,
Nevada, Wyandot County, O.
My Dear Sir:

This leaf blight has been under study here for some time. I first observed it about three weeks ago and associated with it then were very large numbers of plant lice (greenbugs). When the fine weather came on the para-

sites killed off the plant lice and since then the leaves have kept dying in most localities without our being able to explain just why this kept up. Possibly the lice attacks had something to do in the beginning, and the turning to hot weather some more. We do not expect an ordinary oat crop and especially with the later sorts. Early sorts ought to make 3-4 of a crop here but the later sorts little more than 1–2 crop, I fear.

A. D. SELBY."

"Wooster, O., 7-22, 1907.

Mr. F. P. Stump,
Convoy, Van Wert Co., Ohio.
My dear Mr. Stump:

You have doubtless seen the press bulletin issued by the Station with respect to this leaf blight of oats. In the beginning some four weeks ago the crop of aphides (green bugs) was so great as to be held responsible. Later on the leaves continued to blight even after the parasites had killed off the plant lice. Possibly for physiological reasons, the leaves continued to break down.

A. D. SELBY."

"Wooster, O., 7-22, 1907.

Mr. C. P. Oferholtzer,
Hoytsville, Wood Co., Ohio.
Dear Sir:

The head of oats which you send shows what we call "blast" and this serious blast is no doubt due in part to the leaf blight that has been prevailing.

A. D. SELBY."

The severity and nature of the disease is quite readily understood from the above quotations. Though worded differently and emphasized from different standpoints, yet it is quite conclusive that the same general type of trouble was evident in all cases, except possibly the one reported from Connecticut in 1906. The writer finds that the disease differs greatly in its field aspects. Only under the most favorable weather for the spread and developement of the disease, does the trouble assume such pronounced and severe characteristics as were manifested through the central and eastern states in the season of 1907. Under weather conditions more conducive to the growth of oats, and less suitable for the aggressive action of the parasites, the appearance of the trouble becomes entirely changed; leaves which were but partially infected and which under trying conditions would have turned brown in less than a week, under favorable conditions take on a light, yellowish color and may even assume later a natural green. Extensive observations were made upon the disease in the field and under control conditions in the greenhouse, and it is evident that the disease manifests its presence by changes in color varying from a light yellowing, which apparently checks but little the growth of the oats, to a pronounced reddening, which in severe cases kills the blades, leaving only the younger leaves and the central axis alive.

COMMENTS UPON THE ABOVE EXTRACTS.

In a review of previous literature upon this oat blight it is apparent that in only one instance has definite infection work been carried on to determine the cause of the disease, in which case Galloway and Southworth find two bacteria; one of which, they report, produces the blight when inoculated into the oats. This work as reported in the above citation covered but one phase in the study of the disease, and apparently required verification before it could be accepted. A fuller and more extensive report is desired from these workers, covering the several phases of this disease, in order that the organisms may be limited and the nature of the disease more fully understood.

G. P. Clinton, in the 1906 Report of the Connecticut Station, stated that he found no bacteria associated with the yellowing of oats as prevalent that season. From his report it would appear that probably only microscopic examination was made. If such was the case and no cultures were run, it could yet have been a bacterial disease, and the organisms easily missed. On the other hand, cultures would quickly show whether bacteria were present or not. He doubts whether the disease is identical with the bacterial disease noted in the western oat districts.

From a careful study of Pettit's work and notes in Michigan in 1907, (Bul. 251, Mich., March, 1908) it appears rather clear to the writer that the oats in that state were subject that season to both the thrips injury and the bacterial blight. His careful description of the field manifestations, and his illustration, Fig. 3, p. 114, are very typical of the bacterial blight. His illustrations, Figs. 4 and 5, on the other hand are very typical of insect work. It is possible that the thrips were a means in the distribution of the bacterial blight.

In reviewing the literature on the 1890 outbreak of oat blight, we find Galloway and Southworth note: "The disease (ascribed to bacteria) extends from New England to Georgia, and from the Atlantic Coast as far west as Indiana and Illinois. It is not present in Michigan." In notes upon the same year (1890), F. L. Washburn, writing in Bul. 108, p. 264, Minn. Experiment Station April, 1908, on the work of *Toxoptera graminum* says: "In 1890 it was found in injurious numbers on wheat in Indiana and in certain sections of that state the oat crop was a failure through its ravages." It is even possible that the diseased condition of oats in Indiana as noted by the two different writers above for 1890, was due to the same causes, and resulted from the combined work of aphides and bacteria.

The description of the field conditions, given by the others quoted, are all apparently very similar to those given by Galloway and Southworth; and although the causes assigned are, in general, entirely at variance, the writer believes the disease in each instance is the same, and due to bacteria as isolated by the authors noted above; however, instead of assigning the cause to *one* of the organisms, the writer finds the disease to result from a mutual relationship of the two organisms. That this conclusion is correct appears evident from experiments carried on the past two seasons, (see p. 107 and following).

THE BLIGHT DISEASE NOT RESTRICTED TO OATS.

Among the observations made by others in the past upon the blight disease, there are several in which are noted somewhat similar troubles upon wheat[8], grasses[10], alfalfa[3] and other crops[2 3 10]. The writer has carried out much preliminary culture work on the several different kinds of plants which have shown yellowing or blight symptoms, and although this work has not been supported by extensive inoculations as with the oats, the evidence is sufficient to show that the disease may and does affect some of the more susceptible varieties of other plants.

During March, April and May of 1909 inoculations were made in the pathologium on wheat (Gypsy and Poole) and corn, on three different occasions, covering periods of different atmospheric conditions. In no instance did either of these varieties of wheat show signs of infection; however, with the corn, during a cloudy, moist period, several of the lesions spread quite rapidly, from which at a distance of twelve inches from the point of inoculation, by means of plate cultures, the organisms of the disease were separated.

During the present growing season (1909) careful observations have been made on all the varieties of wheat, oats, barley and other crops grown at the Station, for the appearance of this disease. On one variety of wheat, known as Extra Square Head, recently brought here for trial, the blight at a period favorable for its development showed quite extensively. Cultures readily showed the specific organisms to be present. Among the other wheat varieties not a trace of the disease could be found.

There are on wheat and other plants several different fungi, which in their preliminary attack bring about a yellowing that could, off hand, easily be classed with the bacterial blight of oats. Mildew and rust on both wheat and oats may cause yellowing in moist, cloudy weather, which when followed by hot, clear, droughty weather, will cause the blades to turn quite red.

The leaf-spot of alfalfa when severe may cause yellowing. The same is true in leaves of other plants affected with fungous troubles.

As is noted elsewhere, among the oat varieties considerable difference is seen in resistance to this disease.

Among the barleys grown at the Station, one variety, known as Primus, showed a susceptibility to the disease even more marked than did the Wideawake variety among the oats. The Oderbrucker variety of barley also showed an occasional blade infected. These observations were verified by cultures.

What appears to be the same disease has been observed on the blue grasses and timothy; in these cases, however, instead of the blades yellowing, the disease appears restricted to the culm, at heading time, causing, just above the upper joint, a limited lesion which kills the upper part of the stem and causes the head to dry up or blight. This type of injury, off hand, appears similar to insect work, but examination by stripping down the sheath, fails to show that insects are present, or signs of boring; cultures and microexaminations reveal blight bacteria as the cause. These observations have not been followed up by inoculation work. Infection just above the upper joint would appear to be a matter of spattering by rain above the sheath, and running down between the sheath and stem rather than infection from below, passing upward through the vascular system.

During the growing seasons of 1908 and 1909 considerable culture work was done upon yellowing alfalfa, especially upon those plants showing much yellowing and little leaf-spot (*Pseudopeziza medicaginis*). In many instances the presence of bacteria, in the stem and upper leaves, sometimes in large numbers, showed conditions entirely abnormal. The significance of these conditions requires much further investigation. The writer is of the opinion, that alfalfa, on many of our soils, has to contend with certain bacteria which are somewhat specific in their attack upon the plant. Whether these bacteria are the same as those which cause oat blight or not, has not been worked out; however, upon preliminary plating they are very similar.

As noted elsewhere (p. 122) it is probable that thebacterial flora has much to do with the health and growth of certain crops. In this respect alfalfa may be much more exacting than many of our other crops. Experiments carried out in the pathological garden in 1908 and 1909, in soil above the average in fertility, on which were planted red clover, alsike and alfalfa, showed that the red and alsike clovers produced an excellent growth, while the alfalfa was very weak and yellow. Leaf-spot was present on the alfalfa, but not to such an

extent as to account for the weak, yellow growth. An examination of the root systems showed the red clover and alsike to be abundantly supplied with nodules, while the alfalfa had none on many plants and very few on any. Plate cultures made from leaves and stems of the alfalfa showed many internal bacteria, while the red and alsike clovers showed no such abnormal condition. From such evidence it seems probable that either certain specific organisms, or the bacterial flora and its by-products, were not favorable to alfalfa.

DISTRIBUTION OF THE BACTERIAL BLIGHT OF OATS.

From the literature quoted it is very apparent that the disease is of wide distribution. Depending on seasonal conditions the disease manifests itself from the Canadian lake provinces on the north, to the gulf states on the south, and from the New England and middle Atlantic states on the east, to Illinois and states south thereof, on the west. The writer is of the opinion that not a season passes but the disease shows itself in at least a limited way in some locality of the area included above. It requires but ten days to two weeks of favorable weather to bring about preliminary infection. The amount of this infection apparently depends upon the height of oats, the amount of spattering, association of insects, and the continuance of cloudy, humid weather.

AMOUNT OF LOSSES OCCASIONED BY THE BACTERIAL BLIGHT OF OATS.

It is very difficult to estimate the exact amount of loss occasioned by an outbreak of fungous or insect trouble, owing to the fact that several factors are always at work. The plant pathologist is inclined to emphasize the destructive work of fungous and bacterial diseases, while on the other hand the entomologist chiefly sees the work of the insect. If we are to draw our conclusions from a general summary of previous literature on oat blight we can readily see that the losses have been very large at times. The seasons of 1890 and 1907 as well as 1908, were the ones in which the oat blight was by far the most general and destructive. A comparison of the yields in Ohio for these seasons, with the average yield for the past 18 years, shows a shortage respectively of 36.7, 24.3 and 14.4 percent, or stated in bushels per acre, for the above three seasons the yield was respectively 19.8, 23.7 and 26.8 bushels as compared with an average of 31.3 bushels per acre for the past 18 years. (See Table II, showing acreage, yield, etc., from 1890 to 1908 inclusive).

The literature quoted clearly points out the losses as indicated by field conditions. That these losses in some localities have been very much in excess of those in others is evident from the observations noted in the correspondence (See letters, pp. 97 to 101).

Several of the writers indicated the prevalence of the disease with much loss for three seasons consecutively. Such prevalence of the disease means that these certain localities have been subject to an excess of rainfall, cloudiness, etc., furthered by the soil becoming filled with the organisms responsible for the disease.

TABLE I: Showing oat acreage, yield and seasonal conditions in Ohio from 1890 to 1908 inclusive.

Year	Acreage	Bushels produced	Yield per acre	General condition of growing season
*1890	959,012	19,049,033	19.8	Season very late, seeding much delayed through excess rains, oats late, badly blighted.
1891	879,463	26,515,935	30 1	(Failed to obtain data.)
1892	827,823	22,541,473	27 2	Very wet and unfavorable for seeding. July very droughty
1893	856,235	24,537,989	28 6	April and May very wet; June and July droughty, oats short.
1894	1,051,773	31,991,896	30.4	Season as a whole very favorable, with good promise.
1895	1,095,142	34,013,739	31.06	May favorable for acreage. June and July condition generally low.
1896	1,262,805	36,027,464	28 5	Very favorable season for large acreage. Growing season good. Large oat crop is the prospect.
1897	1,052,605	30,563,033	29.	May very wet, oat seeding generally delayed. Acreage small. June and July conditions fair.
1898	976,902	30,694,432	31.4	May not favorable for large acreage. Much injury in June on low grounds from heavy rains.
1899	969,565	33,296,912	34 3	Oat seeding rather late Drought through June and July, plants short, but filling well.
*1900	1,251,248	43,193,577	34.5	May favorable for large acreage. but rather dry for good growth. July very favorable.
1901	1,053,876	33,936,143	32.1	Seeding late, but June quite favorable, though heavy rains. July favorable.
1902	1,188,947	46,789,843	39.3	May favorable for acreage and growth; June conditions fair; July fair except on low ground, injury from rains.
1903	1,213,228	37,305,993	30.7	May favorable for large acreage, but quite dry. June conditions good. July conditions good. Some red rust.
1904	1,467,052	58,312,740	39.7	May very favorable for seeding. June favorable. July favorable.
1905	1,449,112	49,731,954	34.3	May very wet; June conditions fair. July oats doing nicely.
1906	1,343,247	44,179,782	32.9	May, heavy rains, seeding retarded. June, dry and not favorable for growth. July, oats doing poorly, though slightly better than June.
19 7	1,429,792	33,906,233	25.7	Spring very wet, season late, cold, cloudy, oats generally blighted.
1908	1,281,805	34,363,980	26 8	May unfavorable for seeding. June conditions favorable. July droughty, condition not good.

Average yield of oats for eighteen years, (1890 to 1907) 31.3 bushels per acre.
* From the Ohio Statistics, Report of the Secretaries of Agriculture.
NOTE: The bad blight years for oats, viz., 1890 and 1907 show respectively a reduction in yield of 36 7 percent and 24.3 percent from the average for the past 18 years.

THE OAT BLIGHT CAUSED BY TWO SPECIES OF BACTERIA IN SYMBIOTIC RELATION.

At the present day it is well known that relationships among organisms greatly retard or increase their virulence, and also the possibility of disease production. Dr. W. E. Musgrave[14] emphasizes the importance of symbiosis existing among organisms pathogenic to animals. In reviewing this work[15] W. A. Hooker, in the Experiment Station Record, writes as follows:

"The influence of symbiosis upon the pathogenicity of micro-organisms: Bacterial and animal symbiosis are discussed at length by the author. Many of the phenomena not now understood in the etiology and pathology of disease are said to be due to symbiotic combinations between the micro-organisms. Variability in the virulence of bacteria is one of the most marked features and the reason for this variability is but partially understood. The author concluded that, 'the most promising field for laboratory research in the future will be the study of cause and effect, in the complex relation and interaction of micro-organisms with each other and in their environment of complex symbiosis and the ever changing and multiple conditions found in hosts.'"

The experiments carried out with the oat blight organisms clearly substantiate the statements made by Dr. Musgrave. Not alone is the production of disease apparently very dependent upon the symbiosis of these two organisms, but it is found also that the virulence and viability of the white organism (*Psuedomonas avenae* n. sp.) upon artificial culture media, depend greatly upon the association with the yellow organism (*Bacillus avenae* n. sp.) in mixture. The extent of this interrelation as exhibited in disease production is clearly shown in the illustration, Plate I, in which the two rows at the right were infected with a mixture of the two organisms, while the fourth and fifth rows from the right were infected respectively with the yellow and the white organism separately. Where the mixture was applied the blight resulted in twelve days, but where the organisms were infected separately no typical blight resulted. The yellow organism produced no lesions at all and the white organism produced but limited and non-typical lesions. In carrying cultures through the winter the writer had several series of cultures from different sources in which in some instances the organisms were carried through separately, while in other instances the organisms were carried over as mixtures. In renewing these cultures, at the end of a period of nearly nine months, it was found that the white organism, where carried over in pure culture, in several cases failed to grow, but in every instance where it was carried over in mixture with the yellow organism the viability and virulence of the former organism were more marked than when carried over separately.

[14] Philippine Jour. of Sci., B., Med. Sci. 3 (1908), No. 2, pp. 77-88.

[15] Experiment Station Record, Vol. XX, No. 8, p. 788, 1909.

DESCRIPTION OF PLATE I.

Showing, in the two rows at the right, results of the infection with a mixture of artificial cultures of the yellow and white bacteria (*Pseudomonas avenae* n. sp. and *Bacillus avenae* n. sp.) of the brown blight of oats, inoculated by means of a hypodermic needle, twelve days prior to the time of photographing. The blades in the infected row at the right were inoculated in the leaves about one inch from the tips. In the infected row, second from the right, the plants were inoculated near the base of the leaves and also through the stems; the infection in this row greatly retarded the growth of the plants and several even succumbed to the disease. (See Plate II showing the condition of this row as compared with the check, photographed two weeks later). The row at the left of the infected (three rows from the right) is a check row in which the leaves were pricked with control punctures from which no injury or blight lesion resulted. The fourth row from the right was inoculated with the yellow organism, (*Bacillus avenae* n. sp.) from which no lesions resulted; the fifth row from the right was inoculated with the white organism (*Pseudomonas avenae* n. sp.) and the results were, lesions formed slowly, extending about one-half to one inch from the point of infection, then remained checked. The evidence of the symbiotic relationship existing between the organisms which produce the blade blight of oats is clearly brought out in this experiment. By one eighth.

3-11-09. Original.

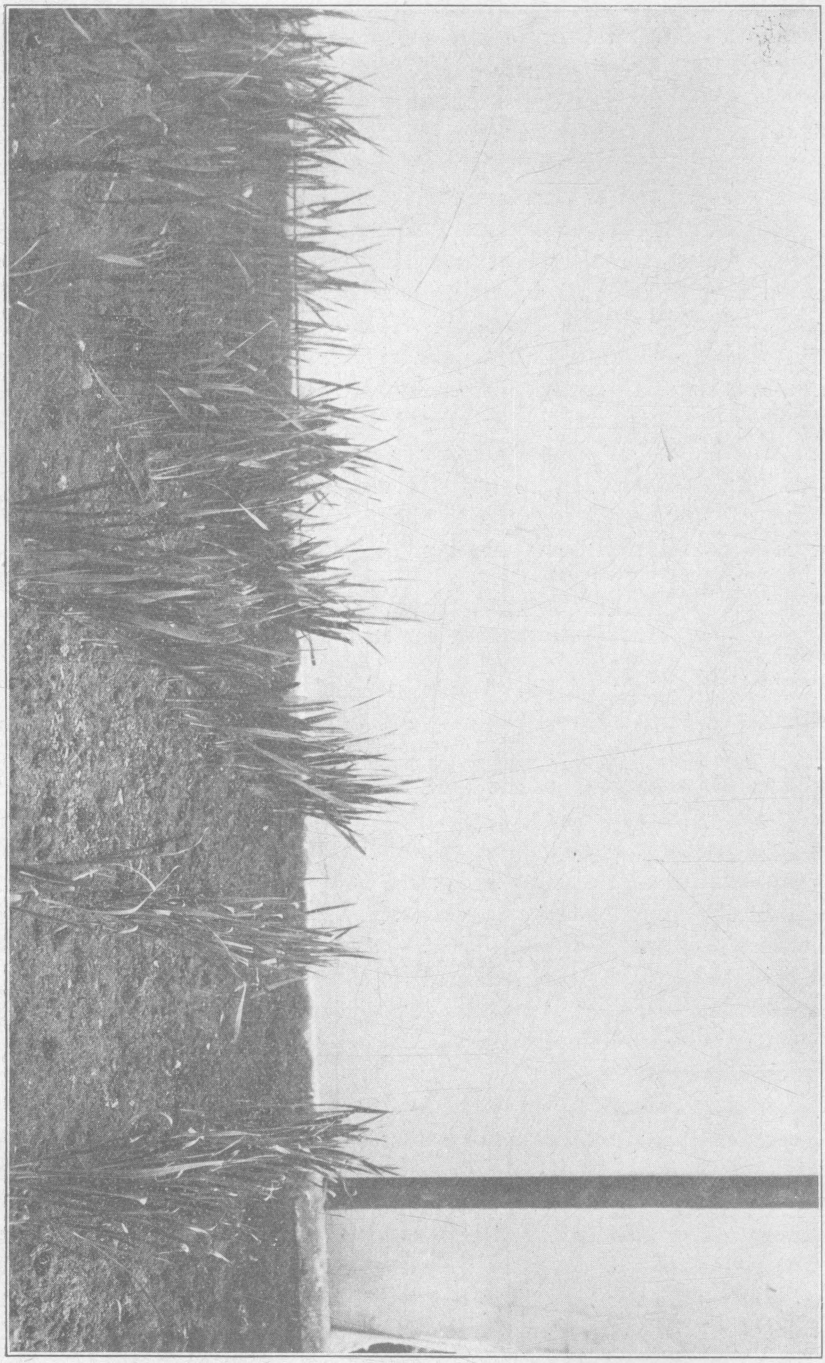


PLATE I.

The influence of mutualism upon the virulence and activity in disease production became much more noticeable when cultures of the white and yellow organisms, which had been carried over separately in pure cultures, were mixed and attempts were made to infect the oat plants, in which case the infection was very slow and required more than a week's difference in time before the lesions became active and typical, as compared with those inoculations from cultures carried over as mixtures. In the latter case the infection was noticeably active from the time of inoculation, clearly showing that the relationship of the yellow organism with the white assisted in some way in keeping up the virulence of the latter. As stated above, the white organism (*Pseudomonas avenae* n. sp.) when inoculated alone into the oat plant produced limited lesions, which were much lighter in color than those produced when a mixture of the organisms was used. In practically all cases of separation of organisms from diseased oats these two bacteria were found more or less abundant, thus again tending to show that the disease is a result of a symbiotic relation between these organisms.

OTHER OBSERVATIONS WHICH POINT TO BACTERIA AS THE CAUSE.

The outbreak of the blight on the Ohio Experiment Station grounds at Wooster, in 1908, caused very little loss, though at one time it was quite threatening. During that season the aphides were more or less associated in the spreading of the infection. One incident pointed very clearly to the probability of the trouble being bacterial. The Agronomy Department carried out a clipping experiment on oats to learn if stand and yield could be bettered. At the time of this clipping the blight was quite conspicuous. The work of the sickle in cutting through the infected leaves was a means of generally spreading the blight throughout the plots. In less than two weeks each of the clipped plots showed a very marked contrast in the amount of disease as compared with the plots which had not been clipped.

Further evidence was gathered the present season (1909) when the blight made its appearance with no insect complications. The disease in the majority of infected leaves began as small yellow spots on different parts of the blades. When these points of infection were numerous the infected areas quickly became confluent, and the collapsed leaf showed a brownish, mottled appearance. Occasionally infection was observed which began on the sheath near the midrib, resulting in a light, yellow streak extending clear to the end of the blade. This streak later turned brown (see Plate XIII).

THE POSSIBILITY OF OAT BLIGHT FROM OTHER CAUSES.

Insect relations: In a review of literature bearing upon the oat blight suggestions are found, that point to other factors that may be important in causing blight diseases of oats. Prominent among these causes are mentioned insects, for examples, such as *Macrosiphum granaria*, *Syphocoryne avenae*, *Toxoptera graminum*, *Anaphothrips striatus*, *Coleothrips tri-fasciata* (*Thrips trifasciata*) and others. The writer would find it somewhat out of his line to experiment with each of these organisms as to the type of injury they would produce on oats. However, in order to obtain data on the relationship of the grain aphides found prevalent upon oats in this vicinity during the seasons of 1907, 1908 and 1909, the writer carried out a number of experiments, all of which show that these grain lice are not the primary cause of the blade blight of oats. Further, that the type of injury produced by them is very characteristic and easily recognized from the bacterial blight. While the blight disease was prevalent in 1908 (June) the writer gathered a number of oat aphides feeding on blight infected plants. These insects were caged with young oats that showed no sign of the blight disease. Ten to twelve days after the caging the blight began to show, while the check outside the cage remained free. It was observed that, on several of the leaves most thickly covered with aphides, no yellowing was apparent. Plate cultures of the yellowing leaves showed the blight bacteria plentiful, while cultures from those blades on which were many insects, but which showed no yellowing, gave, on the contrary, no blight organisms. This pointed to the probability that the aphides were simply means in distributing the disease. Cultures were then made of live aphides to learn whether the bacteria were surviving internally (see lower ill. Plate V). It was evident that the bacteria were present in abundance within the insects and likewise very viable. Inoculations into oats with a mixture of these bacteria, taken from aphides, produced infection resulting in the typical brown blight.

In order to further investigate the relationship of aphides to this bacterial blight, more extensive experiments were planned and carried out during the months from January to June 1909. Oat aphides apparently free, that is, not carrrying the bacterial blight, were confined in a cage on oats, from the time when the oats were two weeks old until they were two and one-half months old. The oats at the age of four weeks were literally covered with the aphides of two different species. (See Plates III and IV and their descriptions). The type of injury caused by these insects came on very slowly and differed greatly from the bacterial blight, infections of which were running simultaneously. (compare Plate IV with Plate X).

DESCRIPTION OF PLATE II.

Showing the effects of the blade (bacterial) blight of oats upon plants five weeks old. The row at the right was inoculated when the plants were one week old (only two leaves out) through the sheath and leaves by means of a hypodermic needle with a mixture of artificial cultures of the yellow and white bacteria (*Pseudomonas avenae* n. sp. and *Bacillus avenae* n. sp.) of oat blight. Ten days after the inoculations the leaves showed the typical preliminary yellowing of the brown blight. Check punctures were made in the control row at the left with no resulting lesions. Twelve days after the row was inoculated, both rows were caged in and grain aphides, two species which were free from, that is, not carrying the bacterial disease, were placed on the sick row to learn in what time the blight would be transferred by these insects to the control row; in two weeks the infections were quite general, being carried by the aphides from the sick row to the check row. This experiment clearly shows the relationship of grain lice to the bacterial blight of oats. By one-sixth.

3-26-09. Original.

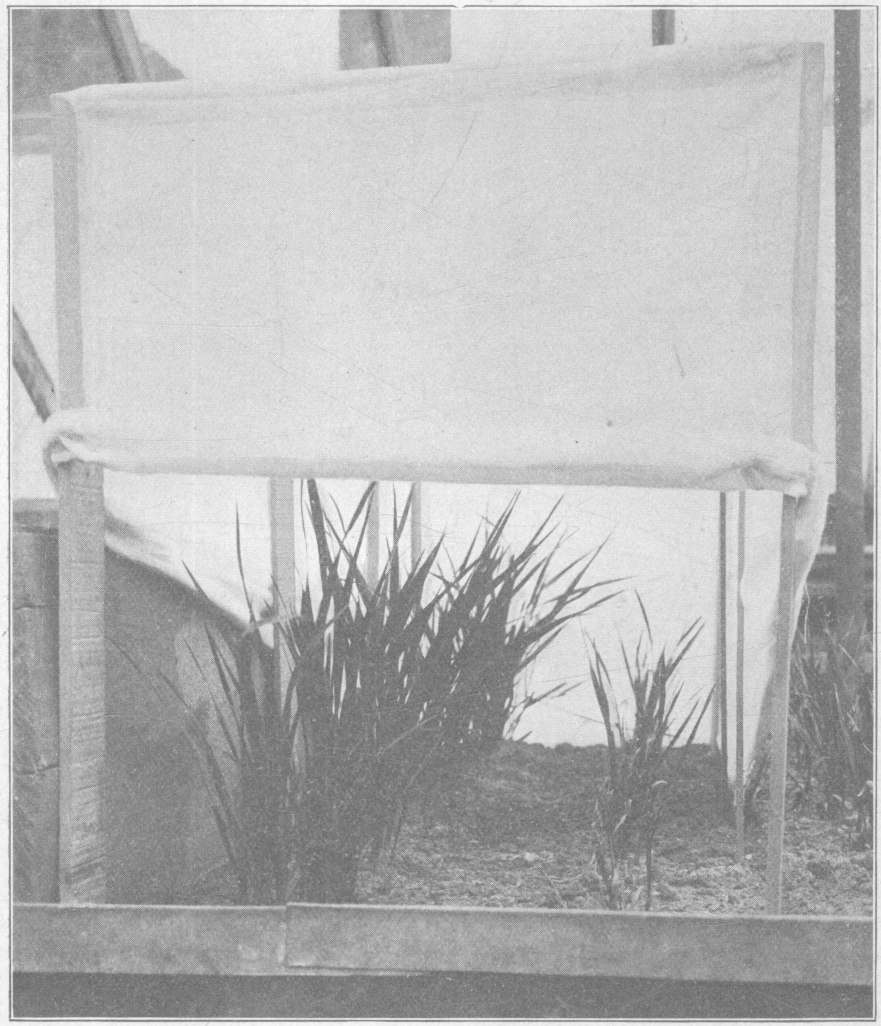


PLATE II.

DESCRIPTION OF PLATE III.

Showing cage containing oats on which two species of grain aphides worked for 2 1-2 months until the oats were literally covered, without producing the blade blight. (See illustrations in Plate IV.) The insects were apparently free from the bacteria which cause the blade blight of oats. The result of the work of aphides on oats differs entirely from the bacterial blight (compare Plate IV, Fig. 3, showing aphis work, with Plate X showing bacterial blight). At the time the above photograph was taken the aphides had been at work seven weeks and literally covered the oats. This experiment clearly shows that grain lice are not the primary cause of the oat blight. By one-sixth.

3-26-09. Original.

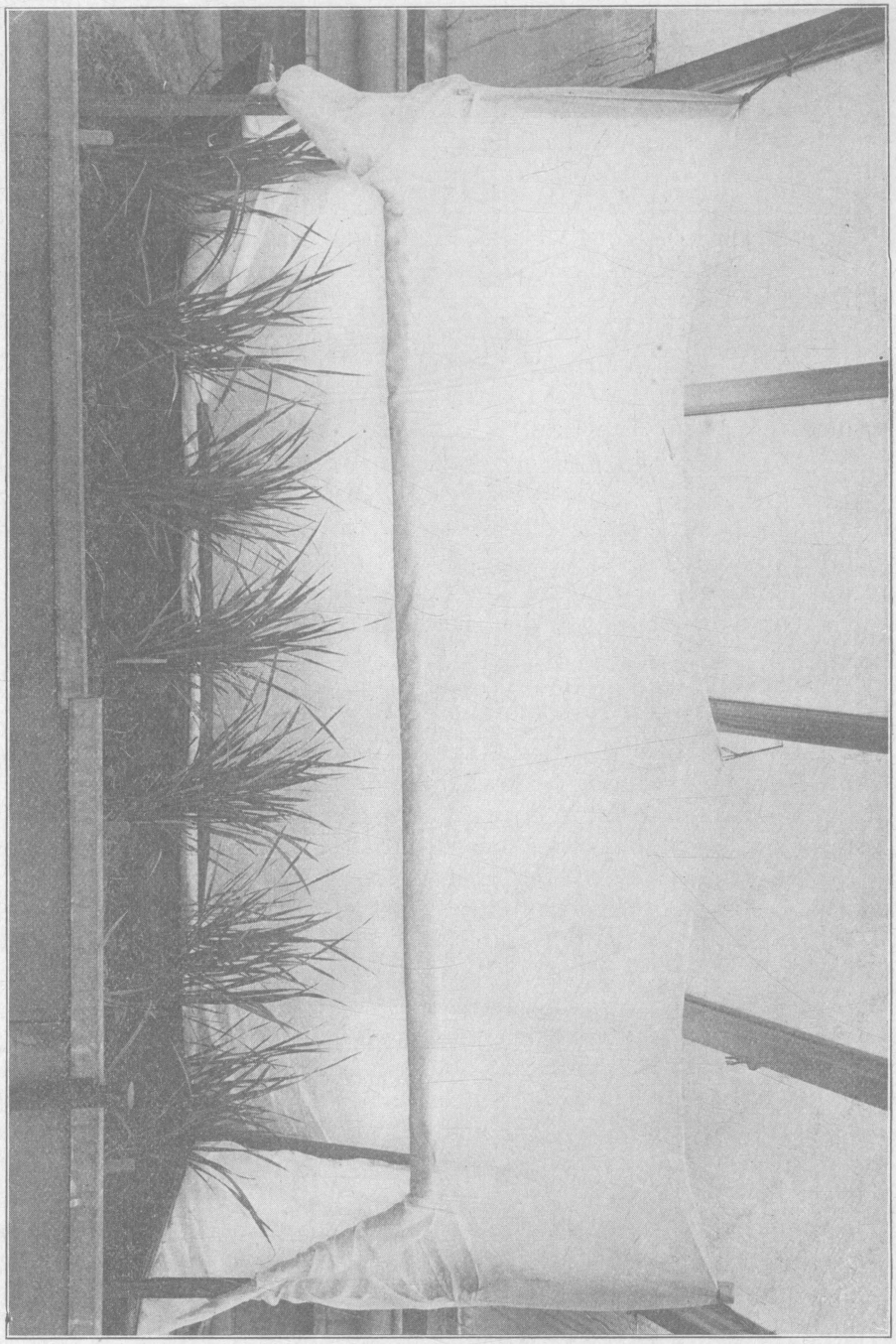


PLATE III

Further, to demonstrate the relation aphides bear to the spread of the disease, an experiment was carried out as follows: Oats well along with the bacterial infection were covered with aphides and caged in, along with a check (healthy) or non-inoculated row, to learn whether it were possible for the insects to carry the disease from the sick plants to the healthy plants, and if so, in what time. This experiment demonstrated that aphides were carriers of the disease, and the time required for visible infection was practically the same as from inoculation by hand, viz., seven to fourteen days; (see Plate II and description). This again verified the conclusions reached in 1908, and showed that aphides are only a secondary factor in the spread of the blade blight.

The direct result of aphis-sucking on oats may be called a blight, but of a nature entirely different from the bacterial blight.

EXPERIMENTS TO DETERMINE THE NATURAL MEANS OF INFECTION.

The general prevalence of the disease would suggest the probability of a trouble surviving in the soil. If such were the case, one would suspect infection to take place through one of two methods, viz., by penetration of the roots, followed by a traversing of the vascular system, finally working its evil effects throughout the leaves, or by rains spattering the disease upon the leaves and the infection taking place through the stomata. Experiments were run to learn whether either of these methods would bring about infection. Following the first method, virulent, artificial cultures of a mixture of both organisms were poured directly upon the root system, the latter being partially uncovered. No infection took place, though the atmospheric conditions maintained were the most favorable. Seed thoroughly soaked in mixed cultures of the organisms previous to planting failed upon growing, to show any blight.

Following the second method the writer took similar cultures and sprayed upon the blades. Infection followed within twelve days, identically of the same type as observed in fields, thus showing that stomatic infection is possible, and probably the chief way; the disease being spattered on by rains. These experiments were carried out in the pathologium in March and April, 1909. In 1908 similar spraying infections were carried out, with this difference, that one series of leaves were slightly bruised previous to spraying. The results were that the leaves previously bruised took the infection much more readily than did the unbruised, though the disease was present on both. This would suggest that heavy, beating rains which cause light bruises on the foliage might be a means of bringing on active infection.

Secondary infection by insects proved a further means in the distribution of the disease, as noted elsewhere. It was thought possible that the disease might be related to the apple blight and that probably aphides were carrying it back and forth, as it has been noted that *Macrosiphum granaria* and *Syphocoryne avenae*[13] pass part of their existence on the apple. The writer gathered twigs of apple affected with blight and numerous twigs covered with aphis eggs, and bred the insects from the latter in cages containing oats. In two series of experiments along these lines, the insects on hatching failed to transfer themselves to the oats, though several generations were produced on the sprouting apple twigs. These experiments would seem to indicate that the eggs found so prevalent on the apple in 1908-09 were not those of *Macrosiphum granaria* or *Syphocoryne avenae*, but probably *Aphis mali*. (See Figs. 1-2-3, Plate XV). Cultures made of the apple and pear blight organism showed it to be entirely different from the white organism, *Ps. avenae* n. sp., of oat blight.

THE BLIGHT OF OATS IN ITS RELATION TO ATMOSPHERIC CONDITIONS.

The disease in its relation to weather conditions is very similar to that of the late blight of potatoes[18], and the blight of pear and apple. The former is known to be a disease prevalent during those seasons when much rain, cloudiness, and wet, muggy weather prevail. Every plant disease may be said to have its certain favorable meteorological conditions. Whetzel[19], writing on the bacterial canker of apple, states:

"It is well known that the "blight" in the twigs of pear and apple trees is more active and severe during a continued period of warm, muggy weather. The same is to be said of the cankers on the limbs and bodies of the trees. It was repeatedly noticed during the past season that the active spread of the cankers was coincident with certain periods of rainy weather. The progress of the disease through the bark is always abruptly checked on the appearance of bright, sunny days. The recurrence of favorable weather may often cause a renewal of activity, the canker spreading and increasing its former extent."

From observations of field conditions and control experiments in the pathologium, the writer is convinced that the chief factors in the spread and production of the blight disease of oats are rains, excess of humidity and cloudiness. Excess of these conditions reduces the vitality of the oat plant and leaves it undoubtedly much more susceptible to the disease. Primary infection is chiefly stomatic, resulting from the spattering of the organisms upon the blades by the rain. Following such means of infection it would be

[18] A. D. Selby, Ohio Naturalist, Vol. VII, No. 4, pp. 79-85, 1907.

[19] The Blight Canker of Apple Trees by H. H. Whetzel, February, 1906, Bulletin 236, Cornell University Experiment Station.

logical to expect the most rapid spread of the disease during periods of rainy, cloudy weather. Control experiments, in which the air was kept nearly saturated and plants well watered, readily showed that these were the conditions most favorable for the aggressive growth and spread of the disease. Under such conditions the amount of infection following inoculation was nearly 100 percent. On the other hand, under experiments in which the air was kept dry, the plants sub-watered, and in which the sun was bright, the disease was quickly checked and the plants quite readily outgrew the injury. The percent of infection following inoculation under such conditions was very small.

The writer, in carrying out experiments under Prof. Bolley, of the North Dakota Experiment Station[20], in the study of the ascension of sap in tree medication, observed that, on days of much sunshine and little moisture in the atmosphere, the ascension of sap and the capability of the tree to feed were excessive, as compared with those days when the atmosphere was nearly saturated and the sky heavily hung with clouds. In the latter case it was observed that often the tree, instead of being capable of feeding, actually had an outward or back pressure which could be compared to the spring flow of sap during sugar harvest. It is believed by the writer that this stagnation of the sap within plants during moist, cloudy weather offers to certain specific organisms a medium very suitable for their growth, while on the other hand, the plant under such conditions is prohibited from producing protective enzymes which are more or less capable of destroying or preventing the invasion of bacterial parasites. A cold or cool atmosphere, other conditions being practically equal, is more favorable for the spread of the bacterial lesions, than is a warm atmosphere. This was clearly proved by experiments running simultaneously under cool and warm conditions in the pathologium during February and March, 1909. These experiments were duplicated with similar results. In the cool room, which was directly connected with the warm apartment (the temperature in the latter being maintained by artificial heat) the lesions spread with much more rapidity than those in the plants under warm conditions. This would appear to be the prevailing condition in 1907 (see Table II, p. 121).

In the case of the oat blight, should the disease reach the stage in which the leaves are generally yellowed, and following which, the weather suddenly changes from a cloudy, moist condition to that of bright sunshine with quick drying, the extent of the injury becomes greatly aggravated. The majority of infected leaves quickly take on a brown color and entirely collapse.

[20] Fourteenth Annual Report of the N. Dak. Agric Exp't. Sta. for 1903 pp. 55-58.

The data summarized in Table II, pp. 119-121, show the meteorological conditions for the years 1890 to 1909 inclusive. By a glance at this table, the season of 1907 (the year of general oat blight), is to be noted as very abnormal throughout the growing period in April, May, June and July. The temperature for these months ranged respectively 7.2, 6.8, 4.0 and 1.3 degrees below the average normal. The general cloudiness was very excessive. These two factors, together with the prevailing wet spring, were ideal for the activity of the bacterial blight. That low temperature is not the chief factor in blight production is evident when we compare the growing season of 1890 with that of 1907, in which former year the blight was much more severe. The temperature variations in 1890 for the months of April, May, June and July were +1.5, —1.4, +3.8 and —6.2 respectively, from the normal. The month of June, the time when the greatest blight distribution and injury take place, shows a high average temperature.

TABLE II: Showing the variations in mean temperature and rainfall in Ohio for the months of April, May, June and July from 1890 to 1909 inclusive. Also number of cloudy and partly cloudy and rainy days for the same period.

	1890				1891			
	Temp. variation from †normal	Precipitation variation from †normal	Cloudy days Total Partial	Rainy days Total + traces	Temp variation from †normal	Precipitation variation from †normal	Cloudy days Total Partial	Rainy days Total + traces
April	+1 5	+ .68	18.5 / 8.8	*12+2	+2	—0 57	18 / 9	*12+3
May	—1.4	+1.25	23. / 10.9	17+2	—1	—1.84	19 / 10	11+2
June	+3 8	+ 65	18 8 / 14.2	15	+2	+0 85	17 / 12	15+1
July	—0 2	—1 38	13.2 / 10 3	7+2	—4	+0 41	15 / 10	11+1
	1892				1893			
April	—1	+0.56	22 / 11	14+3	+0 6	+3 29	25 / 10	18+3
May	—1	+2 09	25 / 11	17+2	—1 3	+0 37	25 / 11	12+3
June	+3	+1.42	21 / 13	19+3	+0 7	—0 74	21 / 15	14+1
July	N	+0.37	16 / 12	10+3	+1 6	—0 88	16 / 13	9

* Data in these columns taken at Wooster, Wayne County, O. The other data is the average rom all other weather stations of the state.

† See bottom, p. 121.

TABLE II: Continued.

	1894				1895			
	Temp. variation from †normal	Precipitation variation from †normal	Cloudy days Total Partial	Rainy days Total + Traces	Temp. variation from †normal	Precipitation variation from †normal	Cloudy days Total Partial	Rainy days Total + Traces
April	+0 6	−0.71	19 / 8	*12+4	+1.6	−0.85	19 / 11	*10+1
May	+0.4	−0.55	23 / 12	18+3	+1.3	−4.34	18 / 11	8+4
June	+1.2	−1.33	15 / 12	8+4	+1.7	−1 40	15 / 10	3
July	+1.3	−1.66	14 / 12	6+2	−1.2	−1.12	24 / 14	7+2
	1896				1897			
April	+6 3	−0.16	20 / 10	11+3	−1.2	+0.30	11 / 10	12+3
May	+7.5	−1 55	19 / 13	15+3	−3.9	+0.05	20 / 12	11+2
June	−0.7	+0.87	20 / 15	17+2	−2.0	−0.97	17 / 13	7+4
July	+0 3	+4.63	11 / 12		+2.4	+1.09	19 / 14	12+3
	1898				1899			
April	−3.0	−0 60	18 / 9	9+4	+2.2	−1.58	21 / 12	11+5
May	+1.	+0.12	21 / 11	14+3	+2.4	+0.69	28 / 17	14+4
June	+1.5	−0.90	13 / 10	6+4	+1.2	−0.56	12 / 8	11+6
July	+2.8	+0.40	16 / 12	9+7	+0.2	+0.22	18 / 12	13+2
	1900				1901			
April	+0.5	−1.01	16 / 8	8+3	−3.8	+0.48	20 / 5	14+3
May	+1.9	−1.07	18 / 11	8+3	−1.8	+0.38	21 / 11	16+4
June	−0.5	−0.42	18 / 11	12+4	+0.7	+0.87	18 / 13	17+2
July	+0 4	+0.73	16 / 12	9+3	+4.4	−1.25	12 / 10	4+3
	1902				1903			
April	−2.2	−0.68	20 / 9	10+5	0.0	+1.26	19 / 7	13+4
May	+1.7	−0.48	17 / 11	7+4	−2.4	−0.72	14 / 9	8+3
June	−3 3	+3.95	19 / 12	14+6	−5.3	+0.11	21 / 11	13+4
July	+0.2	+0.78	15 / 11	12+1	−0.9	−0.08	15 / 12	7+2

* See bottom, p. 119. † See bottom, p. 121.

TABLE II: Concluded.

	1904				1905			
	Temp. variation from †normal	Precipitation variation from †normal	Cloudy days Total Partial	Rainy days Total + Traces	Temp variation from †normal	Precipitation variation from †normal	Cloudy days Total Partial	Rainy days Total Trace
April	−5 4	+0.66	22 / 8	*15+4	−1 4	+0 35	19 / 8	*10+5
May	−0.5	+0.16	19 / 9	14+5	−0 6	+2.06	19 / 10	15+2
June	−1.6	−1.06	17 / 10	10+5	−1.9	+0·75	17 / 9	11+3
July	−2 6	+0.22	16 / 11	10+4	−0.8	+0 09	19 / 12	12+4
	1906				1907			
April	+2.3	−0.96	16 / 8	8+3	−7 2	−0.01	22 / 7	14+3
May	+0.1	−1.46	18 / 10	9+2	−6.8	−0.20	20 / 10	12+3
June	+0.1	−0.53	18 / 12	8+5	−4.0	+0.81	17 / 9	15+2
July	−1.8	+1.17	17 / 11	15+2	−1.3	+1.40	18 / 13	15+4
	1908				1909			
April	+1.4	+0.82	18 / 7	13+3	−0.4	+1.3	21 / 11	12+3
May	+1.4	+1.22	22 / 12	15+6	−2.4	+1.1	19 / 10	12+3
June	−0 1	−1.32	13 / 10	10+3	+0.8	+1.9	20 / 12	17+0
July	+0.1	−0 02	16 / 11	13+4				

* See bottom, p. 119.

† 1908 Normals:

	Temp.	Rainfall
April	49.6	2.87
May	61.4	3.50
June	69.3	3 84
July	73 8	4.1

RELATION OF SOIL AND FERTILITY TO THE OAT BLIGHT.

As noted in the literature quoted (see pp. 92, 93) it is quite apparent that the type of soil and the condition of its fertility have little restraint upon checking the distribution of the disease; by this it is not intended to convey the idea that well-drained and fertilized fields do not, under blight conditions, yield more and withstand the evil effects of the disease better than do poorly drained and run-down soils. The facts are that the disease is prevalent in well drained and rich soils as well as on poor and ill-drained soils; but the density of growth of the plants on the better soils tends to prevent spattering; vigorous plants resist the rapid spread of the lesions when infection does take place, and finally recover more quickly from the disease, than plants of lower vitality or weak

and poorly drained soil. Observations would seem to point to the conclusion that the bacteria which cause oat blight are probably more or less persistent soil organisms. If such is the case, it again emphasizes the need of a much greater knowledge of the bacterial flora existing within the soil, how it may be changed, and the influence of the final products upon fertility and growth. It is even possible that during seasons of excess of rain, humidity and cloudiness the bacterial flora so differs, from the normal, as to bring about very marked changes in the soil solutions. In other words, may not some of these troubles which are now spoken of as physiological, be due to detrimental products thrown off in the soil solution by a change of the bacterial flora, this change of flora being the result of a somewhat lengthy, abnormal, meteorological period. The writer is of the opinion that detrimental soil products result more probably from the work of the bacterial and fungous flora of the soil than from the excretions of higher plants.

POSSIBILITY OF THE TROUBLE BEING PHYSIOLOGICAL.

The blight occurring as it does in seasons which are somewhat abnormal would suggest the possibility of the whole trouble being what is often spoken of as physiological. Its appearance in unusual seasons, like 1907, in which the rainfall was in excess, the temperature on the whole extremely low, with now and then a bright, hot day, though as a rule cloudy weather prevailed, would suggest the possibility that these unusual weather conditions brought about an environment unsuitable for the oat crop, resulting in the peculiar yellowing and later in the collapse, so characteristic of the blight. This would suggest a trouble similar to the tip reddening, which may be brought about by a water-logged soil, or an improperly aerated root system. The writer carried out two experiments in the hope of obtaining data along these lines. These experiments were run simultaneously, one under cold or cool conditions, while the second was run under warm conditions. In both, the oats, as soon as the second blade showed, were kept excessively watered and on a part of each bed bacteria of the oat blight were placed on the roots. The results were quite different in the two experiments. The oats kept in the warm house and excessively watered showed a general tip reddening or blight from which no blight bacteria could be cultured; this condition was equal on those infected at roots and those not infected. In the oats growing under cold temperature, very little of this tip reddening could be found; and what did show, produced no bacteria when cultured. This tip reddening from excess of water and non-aeration of soil, may often be observed in

fields where much water has stood. It differs so greatly from the bacterial blight as to be quite easily distinguished. That this general (bacterial) blight is not due physiologically to non-aeration of the soil is readily seen by the conditions prevailing in the fields. As a rule the blight makes its appearance first on the higher grounds as observed by the writer in 1908 and 1909. Van Hook made similar observations in 1907 (see p. 100) and also C. J. Metcalf (see extract from letter, p. 97).

If lack of drainage was the chief factor, the lower areas should first show the blight.

It is well known that excessively low temperatures will bring about abnormal coloration of leaves; such discolorations are everywhere present following the first few cold days of fall. The extremely low average temperatures prevailing throughout the growing season of 1907 were thought to have had much to do in bringing on the unusual blight of oats that season. That such a conclusion based upon this as the chief factor will hardly hold, we discover, when we compare the temperature of the growing season of 1890 with that of 1907, in which former year the blight was much more severe. The data here follow, + = above, and — = below normal average:

	April	May	June	July
1890	+1.5	—1.4	+3.8	—0.2
1907	—7.2	—6.8	—4.0	—1.3

Since the appearance of blight in its severity is generally a matter of the weather conditions prevailing throughout the month of June, we can here readily see that the greatest blight season followed under average high temperatures.

BLIGHTS FROM HELMINTHOSPORIUM SPECIES.

Very often young oat plants show lesions of a brownish purple color, which are due to a Helminthosporium sp., or probably two different species. The first of these appears on seedlings, at the time when the plantlets have only two or three blades (see Fig. 1, Plate XII). This trouble in certain seasons affects many of the seedlings, sometimes as high as 16 percent (see note in description opposite Plate XII), causing a limited injury. The second Helminthosporium blighting is really only a spotting of the oat blades at the time when plants are six inches to 20 inches high. The spots are usually ¼ to ¾ inches long and ⅛ to ¼ inches wide. Such spots cause little or no injury to the plants, and may be passed by with little concern (see Figs. 2 and 3, Plate XII).

DESCRIPTION OF PLATE IV.

Showing in the illustration at the left and center two species of grain aphides at work on oats, at the right is shown the type of injury resulting from aphis sucking; this injury differs entirely from the brown bacterial blight. The aphides here shown are free from, that is, not carrying, the bacteria which produce the blight of oats. The oat blades here illustrated were taken from the cage shown in Plate III at the time when the plants were seven weeks old. Enlarged four diameters.

3-26-09. Original.

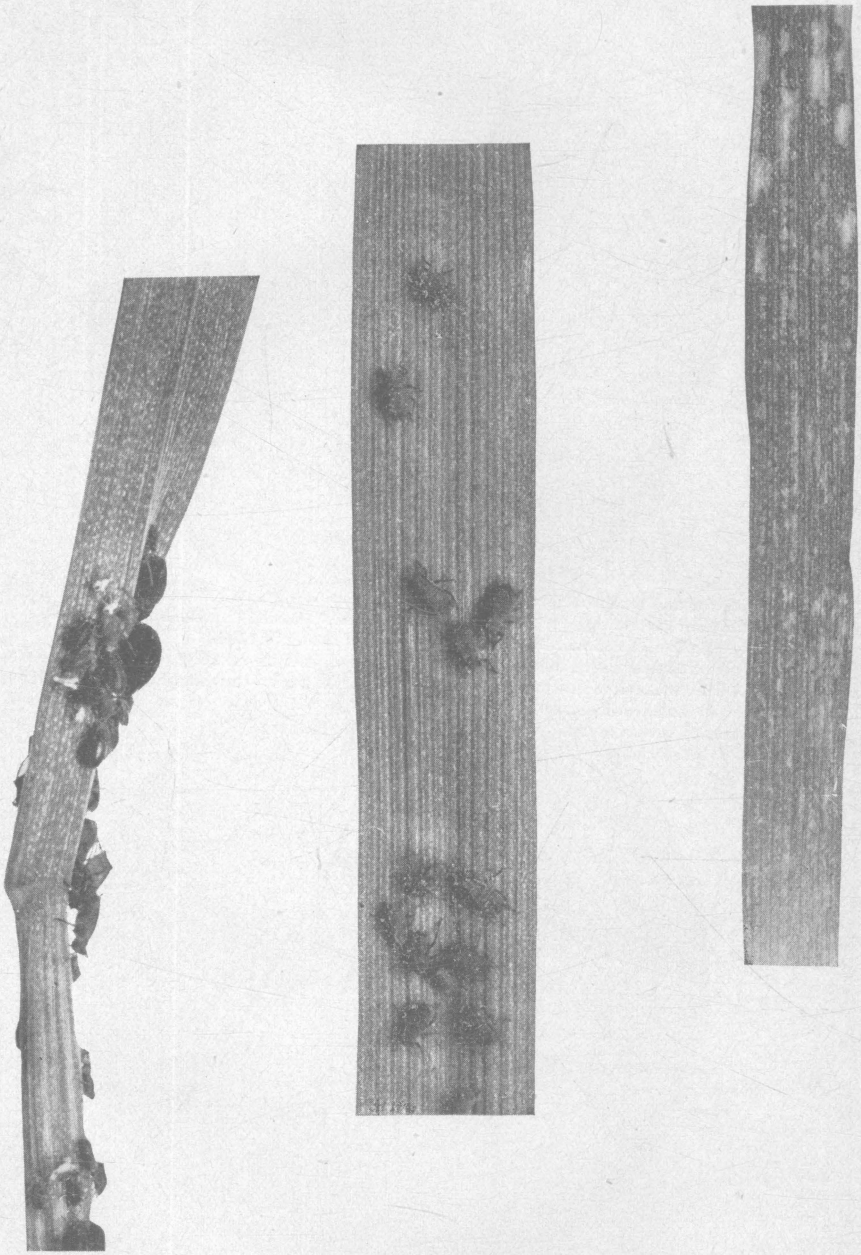


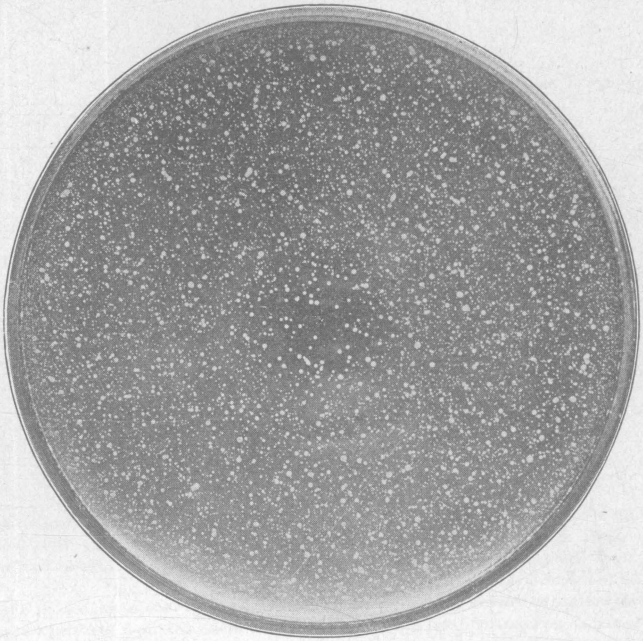
PLATE IV.

DESCRIPTION OF PLATE V.

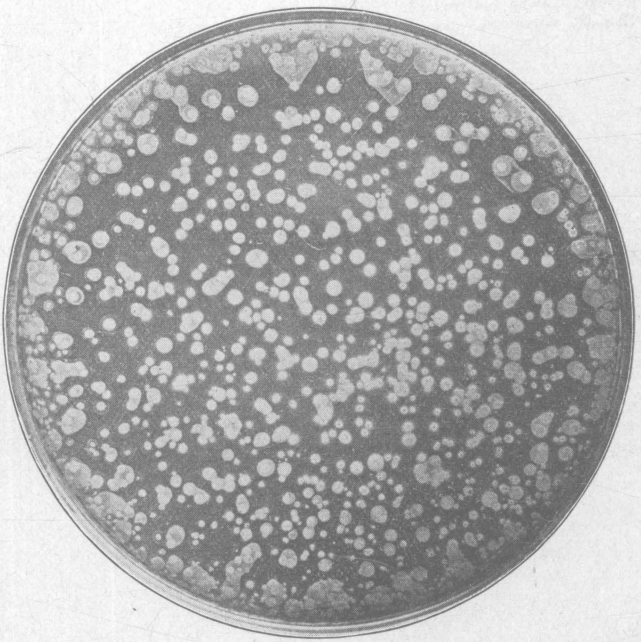
1. Showing colonies of the bacteria of oat blight taken directly from a yellowed oat blade, culture three days on nutrient glucose agar. The colonies are too much crowded to make further growth. A mixture of these organisms when inoculated into oats produced the blade blight.

2. Showing colonies of the bacteria of oat blight taken directly from a live aphis. Mixtures of these organisms when inoculated into oats gave the typical blade blight, thus showing that the grain lice carry at times viable organisms of the oat blight. Cultures three days old on nutrient glucose agar. Both plates by seven-eighths.

6-10-08. 7-13-08. Original.



1.



2.

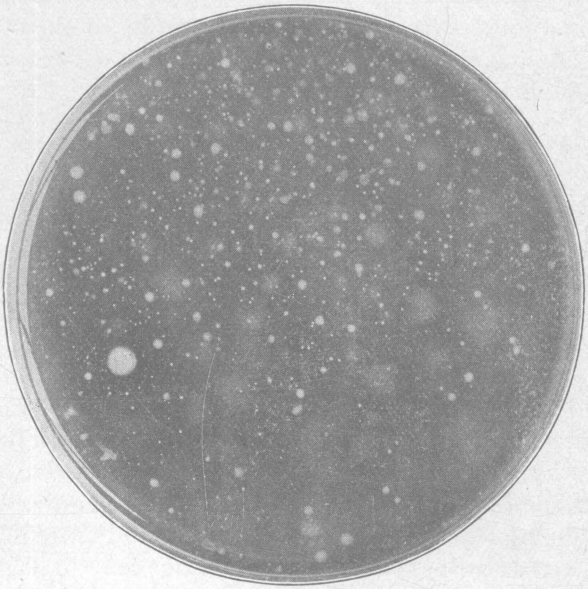
PLATE V.

DESCRIPTION OF PLATE VI.

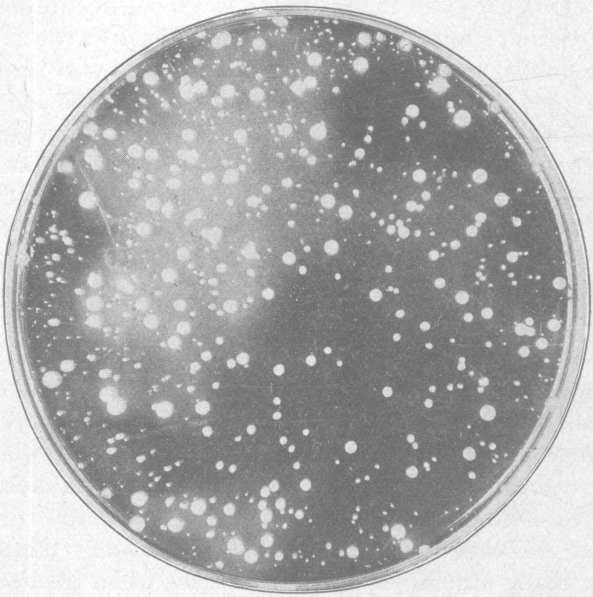
1. Showing a plate culture of the white bacterium (*Pseudomonas avenae* n. sp.) of oat blight on nutrient glucose agar, .5 percent acid to phenolphthalein, in moist chamber six days at 20° C. The graying or fogging of this medium is characteristic. The spreading of the colonies at the bottom of the plate is likewise characteristic.

2. Showing a plate culture of the yellow bacterium (*Bacillus avenae* n. sp.) of oat blight on nutrient glucose agar, .5 percent acid to phenolphthalein, in moist chamber four days at 30° C. The yellow pigment in this organism becomes more or less pronounced as the medium is changed from alkalinity to acidity. Both plates by four-fifths.

3-22-09. 3-20-09. Original.



1.



2.

PLATE VI.

Nematodes occasionally cause a yellowing in seedlings of oats followed by a dying, through their destruction of the stem or root one-half to one inch below the soil. Each of these oat troubles may be easily distinguished from the bacterial blade blight.

KINDS OF INJURY RESULTING TO OATS FROM THE BACTERIAL BLIGHT.

The different manifestations of the disease depend much upon the age and the part of the plant attacked. Observations and experiments made by the writer tend to show that the disease is most specific on the parts of the plant above ground. In the infection work carried out in the pathologium, the writer failed to produce the disease by placing the organisms on the roots. Observations in the field, though not fully substantiating the results of these experiments show however, that among seedling plants, but few become infected by way of root, or that portion of the stem which is underground. In plants beyond the seedling stage it is quite common to find the yellowing lesions following the stem and extending to the very tips of the leaves, sometimes affecting only one side of the blades, and again yellowing the middle or the whole of the blades (see Plate XIII). Just where these lesions begin is sometimes difficult to tell; often they are found beginning on the culm, but more often they originate in the blade and work backwards to the stem. There is no doubt, however, that the disease does at times start in the roots, or that part of the stem in contact with the soil. In older plants it is quite common to find the whole plant showing a general collapse of the foliage, resulting from the disease working backwards into the stem from an early infection of the lower leaves. In many cases of this kind collapse of the upper leaf-tips may occur when bacteria are not present in them; they are, however, present in the lower leaves and lower culms. The usual appearance of the disease is that of a primary yellowing of the blades, which sooner or later is changed to a mottled red and brown. This latter coloring results as the leaves collapse. Sometimes this latter stage, in extreme cases, gives the field the appearance of a severe attack of rust, described by correspondents in the phrase "as red as fire."

This bacterial blight disease is one of the causes of blast in oats. The following data show how directly proportional is the blast of oats to the amount of blade blight. These counts were made during the season of 1909, upon the several varieties of oats and barleys under varying amounts of blight, in the variety plots at the central farm of the Station at Wooster.

Variety	Amount of blade blight	Percent of kernels blasted in the head	Percent of sound kernels in the head	Yield per acre 1909
Improved Am. Oats	Average condition—little blighted	17.2	82 8	73 51
Wide Awake Oats	Average condition—considerably blighted	35.8	64.2	55 42
Wide Awake Oats	Where little blighted	12.8	87.2	.....
Wide Awake Oats	Where quite extensively blighted	22 5	77.5	.....
Wide Awake Oats	Where badly blighted	50 6	49.4	.....
Oderbrucker Barley	Av. condition—Very little blighted	6 1	93.9	37.81
Princess Barley	Av. condition—Noticeable though not bad	28.8	71.2	24.64
Primus Barley	Av. condition—Bad, generally blighted	70 8	29.2	9.01

Observations this season (1909) supported by culture work, show that the heads may be partly or wholly blasted by lesions coming in contact with them. These lesions often begin on the flag leaf and work downward, affecting the head differently, according to its maturity (see Plate XIV), that is, heads entirely covered in sick sheaths are so blasted that they fail to push out at all; others which are just ready to push out at the time when the sheaths become affected, will show more or less blasted kernels. Often the head is halfway out before any part of it comes in contact with the sick sheath, in which case the lower half of the panicle becomes blasted.

The greatest loss to oats from the bacterial blight is due to the injury and collapse of the blades, causing a lowered vitality, with an increase of blast. This injury results, as a rule, from primary infection through the stomata of the sheaths and blades. A smaller loss results from a direct blasting of the heads, due to sheath lesions coming in contact with them. It is also very probable that such specific bacteria, when present in the soil, give rise to products which are detrimental to the oat crop. Just what consequences would result to oats growing in a soil medium filled with such specific organisms as the oat blight bacteria, would be difficult to predict. If the specific lesions in oats result from the effect of a toxin or a destructive enzyme produced by the blight bacteria, then, were these organisms abundant in the soil, it would be reasonable to suppose that the oats would suffer from taking up their specific products. Such may be the very conditions which are actually taking place in those fields showing blight for several seasons successively. This is a phase of soil investigation which should certainly be covered, that is, whether an abundance of these specific organisms in the soil plays a detrimental role against the growth and maturity of oats. *That there is a specific abnormal condition of the oat crop*, is evident from the many observations noted in

the literature quoted. This diseased condition is worse in certain localities than in others, and varies even in fields but little affected. There seems to be some evidence which indicates that these blight organisms in certain small areas, in fields showing limited infection, bring about a condition in the soil which is objectionable to the growing oat plant; if such is the case these areas may be called "oat-sick."

STUDIES IN LIMITING THE ORGANISMS OF OAT BLIGHT.

The field observations noted, and the cultural work herein covered, extend over a period of the past two years. The observations in the field include those of the two growing seasons of of 1908 and 1909, supplemented by the observations made by Prof. Selby and his assistant, J. M. Van Hook, in 1907. The artificial inoculations have been run on six different occasions for periods varying from three weeks to three months, under varying weather conditions. The results all point to the same conclusion, namely, that the disease is caused by the symbiotic relation of two bacteria. During the season of 1908 artificial inoculations in oats in field plots conclusively showed that the yellow organism (*Bacillus avenae*) did not produce lesions, and that the white organism (*Ps. avenae*) would produce but very limited lesions, but when a mixture of these organisms, made directly from crushed leaves, was inoculated, the lesions spread rapidly. This same line of work, duplicated in the pathologium under varying moisture and temperature, gave under favorable conditions exact duplicate of the field work. No typical blight resulted unless both organisms were inoculated into the same plant, conclusively showing the above deductions. The white organisms (*Ps. avenae*) when inoculated alone produced a limited lesion which was light in color and not typical of the lesions of oat blight; since the yellow organism (*B. avenae*) when inoculated alone failed to produce any lesion at all or to make any signs of headway, the active agent in the production of the pathogenicity is *Ps. avenae*. The relation of the yellow organism to the spread of the lesion seems to be that of maintaining a proper nidus for a virulent growth and production of the active toxin or enzyme by the white organism.

A series of plate cultures, run for the purpose of determining the rate of distribution of the organisms throughout the leaf, tends to show that the lesion when the yellow organism is present spreads even more rapidly than do the organisms. That is, yellowing which extended clear to the ends of the leaves often failed to show the yellow organism at all when cultures of the tips were run, and in many instances would show only a few colonies of the white organisms (*Ps. avenae*). In the case where the white organism was

inoculated alone this relation of the bacteria to the spread of the lesion was entirely different, the lesion extending only the distance of the spread of the organism. This line of work would seem to show that the association of the two organisms results in a much more rapid production and spread of the toxin or other products which cause the breakdown of the chlorophyl or the destruction of the cellular work of the leaves. This series of culture work was carried out as follows: Leaves which showed yellowing six to nine inches from the point of inoculation were placed in cultures, using a one-half inch section of the leaf one inch distant from the point of inoculation, and another section six to nine inches from the point of inoculation. In all the plates made from the sections one inch from the point of inoculation, both the yellow and white organisms were found in abundance, while in those plates made from the tip sections of the leaves at a distance of six to nine inches from the point of inoculation, in many there was little or no evidence of the yellow organism and in several of the plates no colonies of the white organism, showing that the lesions are some times more extended than the bacteria.

CHARACTERISTICS OF THE WHITE BACTERIUM OF OAT BLIGHT.

Pseudomonas avenae n. sp.

Following Migula's classification and the numerical system* this organism becomes Ps. 111.2223032.

MORPHOLOGY.

This organism, taken from 24 hour cultures on any of the ordinary culture media, is a bacterium of short, rod shape with round ends, and with few internal markings, having a diameter of .5 to 1 micromillimeter and a length of 1 to 2 mmm. The majority of the organisms measure about ¾ mmm. in diameter, having a length of 1.5 mmm. In hanging drop the flagellate individuals are actively motile, though being limited in number even in the most viable cultures. Occasionally in plates of nutrient agar and in old nutrient glucose agar cultures, the organisms are much shorter, assuming oval or nearly coccus forms. In agar-hanging-block-mounts the organisms separate quickly upon division, very seldom being found in chains of three or four.

Staining Reactions: The organism does not retain Gram's stain.

Endospores: Bodies which are apparently endospores are found in old cultures of the organisms such as those which have run for one month or more. When mounts of such cultures are made, especially those from nutrient glucose agar, and stained with hot carbolfuchsin for three or four minutes, these bodies retain the stain similar to spores. (See Fig. 2, Plate IX). In type, they are

*See Descriptive Chart, endorsed by the Society of American Bacteriologists, December 1907.

similar to the spores found in the anthrax organism, *Bacillus anthracis*. When stained with hot carbolfuchsin they may be decolorized for a few seconds with 5 percent sulphuric acid without losing the stain. Observations were not made as to the growth from these bodies, though cultures which had run nine months before transferring and which had dried up, produced a growth of the white organism, tending further to show that the organism is carried over by more than the vegetative form. Clostridium forms may be observed in nutrient glucose agar in one week old cultures.

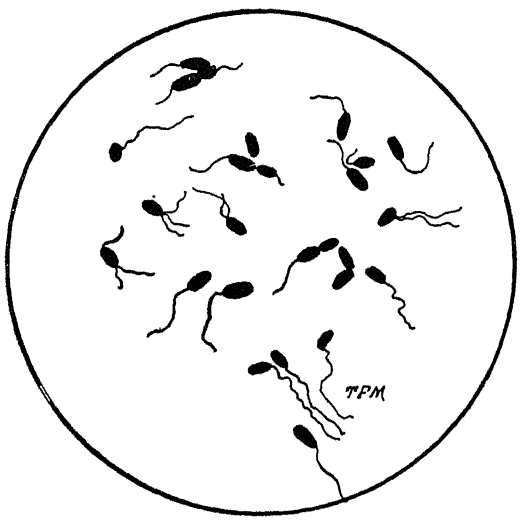


Fig. 1. *Pseudomonas avenae* n. sp. The bacterium which is the active agent in the cause of oat blight. Culture three days on nutrient glucose agar. Drawn from Van Ermengem's stain.

Staining for Flagella: This organism is very difficult to stain in demonstration of the flagella. The film on cover slip appears to fix poorly and in many attempts the film loosens. This is especially true in the use of Van Ermengem's stain, but not so marked in the use of Pitfield's or Muir's modification of Pitfield's. In the use of the two latter stains, though the film holds fairly well, it is found upon examination that the flagella are delicately stained and also very scarce unless one is fortunate in fixing and equally so in catching the growth before the flagella have been cast off. Much difficulty is met with in attempting to limit the number of flagella. In general only one polar flagellum is present. After a careful study of a number of slides, covering over a month's work on staining, the writer has concluded that there is found occasionally individuals having two or three polar flagella, but these are very few (see Fig. 1. p. 134). The cultures have been carried out in triplicate, using the organism from different sources and the work being run at different periods of time. This work on limiting the organism through cultures began in January 1909, and continued through June.

CULTURAL CHARACTERISTICS.

Plate work: Little difficulty is met with in obtaining the two organisms of oat blight as a mixture from the sick blades. The writer sterilized the blades externally with a solution of corrosive sublimate made with two grams of bichloride of mercury in 1000 cc. of equal parts of commercial alcohol and water. The leaves were placed in this solution for one to one and one-half minutes and were then quickly followed by four washings with sterile water. This disinfection in no way apparently injured the organisms which were internal, but proved very efficient in destroying surface contaminations. When mixed the two organisms make a medium to rapid growth and in two to three days they can be plainly seen. Sometimes the yellow organism predominates, but as a rule the white bacterium, when growth takes place properly, is the predominating organism in numbers, though the yellow organism is always the first visible and in some instances, when the medium is slightly unfavorable to the white organism, it may in growth overwhelm the latter. Medium that has become too much dried out is very unfavorable for the white organism (*Ps. avenae*). The growth of the white organism as a whole, when taken in pure culture, is somewhat feeble on the ordinary artificial media, and a number of transfers seem to reduce its viability greatly, so that in many instances it fails altogether to make growth. The culture media most suitable for continued growth appear to be nutrient glucose agar and nutrient saccharose agar.

Agar stroke: Growth very slow, usually visible in three or four days, scanty to moderate, filiform, rather flat, glistening, with margin smooth, opaque to opalescent, non-chromogenic, with little or no odor, having a slimy consistency. The medium, as a rule is turned slightly gray.

Potato plug: Growth moderate, spreading, at first glistening, later dull, smooth, non-chromogenic, no odor, of a slimy consistency.

Agar stab: Growth best at the top, though very thin, white and widespread. Line of puncture filiform, slightly beaded near top, growth soon limited in the deeper medium.

Gelatine stab: The line of puncture becomes visible about the third day. Growth is best at the top and is somewhat limited along the stab, the line of puncture is filiform and slightly papillate. Liquefaction is crateriform and begins in seven to twelve days. In two weeks liquefaction has covered about the upper one-third of a two inch culture (see Fig. 2, Plate VIII); in sixty days the liquefaction is complete. The precipitate is a grayish light yellow.

Nutrient broth: Visible growth is present in three days. Medium slowly clouds with no flocci or pellicle, clouding moderate and persistent, odor resembling decay by *B. subtilis*, Sediment scant but compact, very light yellow.

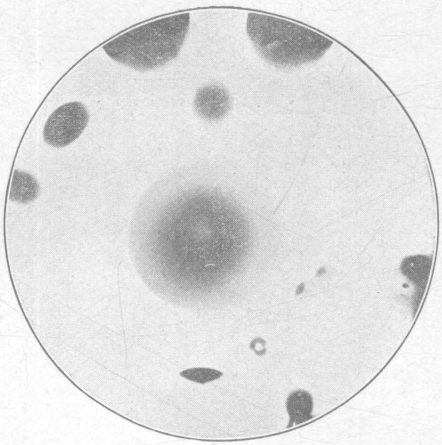
DESCRIPTION OF PLATE VII.

1. Showing a surface colony of the white bacterium (*Pseudomonas avenae* n. sp.) of the oat blight in nutrient glucose agar culture; six days at 22° to 23° C. Enlarged seven and one-half times.

2. Showing a sub-colony of the white bacterium of oat blight in nutrient glucose agar plate culture; six days in moist chamber at 22° to 23° C. Enlarged 65 times

3. Showing sub-colony of the white bacterium of oat blight differing somewhat in shape from the colony illustrated in (2) above. In nutrient glucose agar plate culture; six days at 22° to 23° C. Enlarged 65 times.

4. Showing a sub-colony of the yellow bacterium (*Bacillus avenae* n sp.) of oat blight in nutrient glucose agar plate culture; four days at 22° to 23° C. Enlarged 65 times. (All taken 5-18-09). Original.



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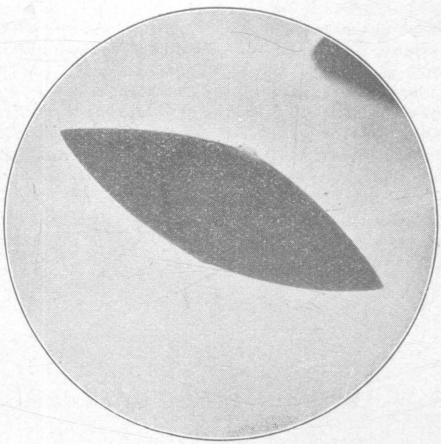

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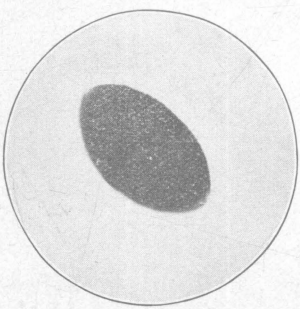

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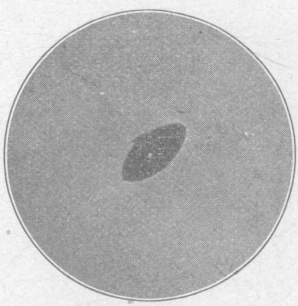

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PLATE VII.

DESCRIPTION OF PLATE VIII.

1. Showing a gelatine stab culture of the white bacterium (*Pseudomonas avenae* n. sp.) of oat blight one week old; temperature 22° to 23° C. (Medium .5 percent acid to phenolphthalein). Natura size. 3-30-09.

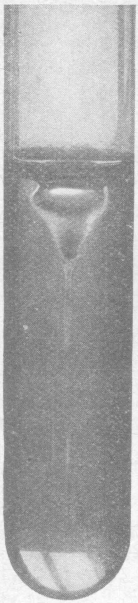
2. Showing a gelatine stab culture of the white bacterium (*Pseudomonas avenae* n. sp.) of oat blight two weeks old; temperature 22° to 23° C. (Medium .5 percent acid to phenolphthalein). Natural size. 4-6-09.

3. Showing nutrient glucose agar (.5 percent acid to phenolphthalein) slant culture of the white bacterium (*Pseudomonas avenae* n. sp.) of oat blight, temperature 22° to 23° C.; two weeks old. 3-21-09.

4. Showing a gelatine stab culture of the yellow bacterium (*Bacillus avenae* n. sp.) of oat blight two weeks old in medium .5 percent acid to phenolphthalein. Temperature 22° to 23° C. 3-30-09.

5. Showing a potato plug culture of the yellow bacterium, (*Bacillus avenae* n. sp.) of oat blight. two weeks old at temperature 22° to 23° C. 3-27-09.

6. Showing nutrient glucose agar (1.5 percent acid to phenolphthalein) slant culture of the yellow bacterium (*Bacillus avenae* n. sp.) of oat blight; one week old at temperature 22° to 23° C. 3-19-09. All original. Natural size.



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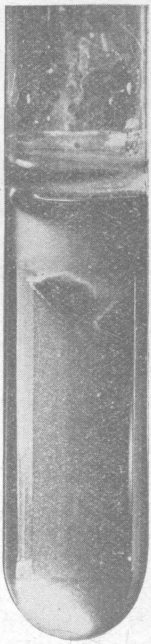

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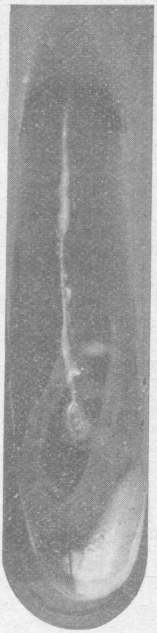

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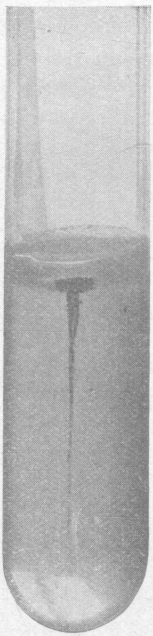

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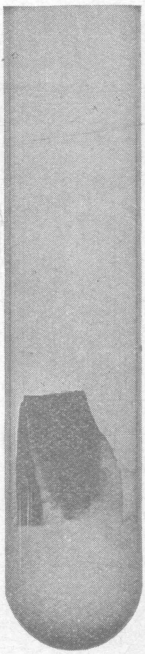

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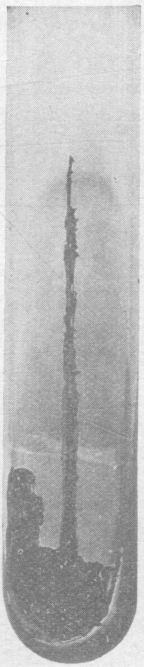

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PLATE VIII.

Milk: No coagulation in thirty days. The reaction is slightly acid and apparently remains so.

Litmus milk: Beginning with the second day the medium shows a very slight acidity which gradually increases up till the 10th day, after which the acidity begins to weaken; no coagulation.

Gelatin colonies: The growth is somewhat slow, colonies becoming visible about the second to the third day. At the end of the 7th day pitting is noticeable. The colonies at three days are white to gray, round, with margins entire; in two to three weeks the pitted colonies become confluent and liquify this medium.

Agar colonies: Growth is very slow; colonies are visible about the third day. Colonies round with smooth surface and edges entire. The internal structure is amorphous, somewhat more dense at center.

Growth: Growth takes place best on nutrient glucose and saccharose agar.

PHYSICAL AND BIOCHEMICAL FEATURES.

Gas and acid production: No gas is produced in the following sugar bouillons: dextrose, saccharose, lactose, maltose and glycerin. Little or no growth takes place in the closed arm of the fermentation tube. The production or change in acidity in each of the above media is as follows. Dextrose, check 1.5 percent acid to phenolphthalein; first day's growth 1.25 percent, second day's growth 2. percent, fourth day's growth 1.82 percent. Saccharose bouillon, check 1.9 percent acid; growth shows no change in four days. Lactose, check, 1 75 percent acid; first day's 1.37 percent, second day's 1.75 percent, fourth day's 1.25 percent. Maltose bouillon, check, 1.87 percent acid; first day's growth 2.25 percent, second day's 1.75 percent, fourth day's 1.57 percent. Glycerin, check, 1.5 percent acid; first day's growth 1.42 percent, second day's 2. percent, fourth day's 1.51 percent acid. These variations are very slight and the conclusions would seem to be that the white organism, *Ps. avenae*, produces but very little change in the reaction of media.

Ammonia: None produced.

Nitrates: Reduced to nitrites in nitrate bouillon.

Indol: No indol is produced,

Tolerations of acids and alkalies: This organism is very sensitive to alkalies, producing only limited growth in .5 percent alkaline medium (to phenolphthalein), and likewise on the other hand it is quite sensitive to acids, making but little growth on medium beyond 1.5 percent acid to phenolphthalein. The optimum reaction for growth appears to be about +10 in Fuller's scale.

Vitality on media: When grown on nutrient glucose agar, and nutrient saccharose agar, the vitality of this organism is quite pro-

longed. Its life on culture media appears to be a matter of spore production, which latter apparently form after several weeks on sugar media.

The thermal death point in young cultures is reached in a ten-minute exposure at 60° C.

The optimum temperature for growth is between 20° and 30° C.

Light is very active in checking the viability of this organism.

Drying quickly kills the organism in young culture, though in old cultures the spores apparently carry it over.

Effects of germicides: This organism in the vegetative state is much more susceptible to germicides, heat, light and drying than is the yellow organism. Killing results in ten minutes in a 1 in 15,000 solution of corrosive sublimate, or 1 in 7,500 of formaldehyde. In a toleration test in nutrient glucose bouillon having one gram of corrosive sublimate in 75,000 cc. and when 1 cc. of formaldehyde in 15,000 cc. was used, the organism failed to grow.

Pathogenicity: Pathogenic in blades of oats (*Avena sativa*), corn (*Zea mays*), timothy (*Phleum pratense*), barley (*Hordeum distichum*), wheat (*Triticum vulgare*), and in the culms and sheaths of the blue grasses (*Poa pratense* and *P. compressa*).

DESCRIPTION AND CHARACTERISTICS OF THE YELLOW BACTERIUM OF OAT BLIGHT.

Bacillus avenae n. sp.

Following Migula's classification and the numerical system* this organism becomes B. 222.2223532.

MORPHOLOGY.

This organism when grown on nutrient glucose agar at room temperature 22° to 23° C., for twenty-four hours is a very actively motile bacillus of short, rod shape with rounded ends, measuring from .75 to 1 x 1.5 to 2 micromillimeters. The majority are about .75 mmm. x 1.7 mmm. Division when observed in agar hanging block takes place quickly, the organisms soon separating; usually found singly, but some times observed in short chains of three or four.

Staining reactions: This organism does not retain Gram's stain.

Endospores: No endospores have been observed.

Flagella: The flagella are many, peritrichiate, long, undulate; easily stained with Pitfield's or Van Ermengem's method.

CULTURAL FEATURES.

Agar stroke: Growth is very rapid and abundant. Filiform, slightly raised, at first white, glistening, later turning somewhat dull, margin smooth, growth rather opaque; the third day turning yellow; growth somewhat mucous: no noticeable odor.

Potato: Growth abundant and persistent, rapidly spreading; diffuse, dull, margin smooth; pigment yellow. Consistency mucous. No characteristic odor.

*See footnote p. 133.

DESCRIPTION OF PLATE IX.

1. Showing the white bacterium (*Pseudomonas avenae* n. sp.) of oat blight from nutrient glucos agar plate, ten days in moist chamber. Carbolfuchsin. Enlarged 1000 times. 4-3-09.

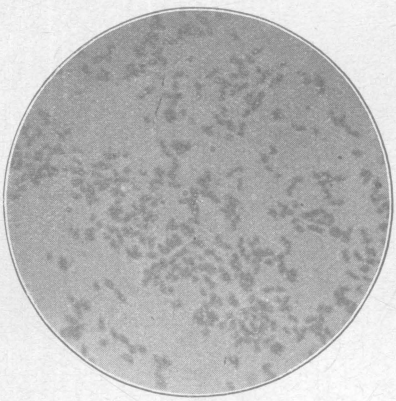
2. Showing what appear to be spores of the white bacterium (*Pseudomonas avenae* n. sp) of oat blight from a two months old culture on nutrient glucose agar stained with hot carbolfuchsin four minutes and decolorized with 5 percent sulphuric acid. Enlarged 1000 times. 5-17-09.

3. Showing polar flagella of the white bacterium (*Pseudomonas avenae* n. sp) of oat blight from a twenty-four hour culture on nutrient glucose agar. Pitfield's stain. Enlarged 1000 times. 5-19-09.

4. Showing polar flagella of the white bacterium (*Pseudomonas avenae* n. sp) of oat blight from a twenty-four hour nutrient glucose agar slant. Pitfield's stain. Enlarged 2000 times. 5-18-09.

5. Showing flagella of the yellow bacterium (*Bacillus avenae* n. sp.) of oat blight from a four days old culture on nutrient glucose agar. Van Ermengem's stain Enlarged 1000 times. 4-3-09.

6. Showing the yellow bacterium (*Bacillus avenae* n. sp.) of oat blight; culture one week old on nutrient glucose agar. Carbolfuchsin stain. Enlarged 1000 times. 4-26-09. All original.



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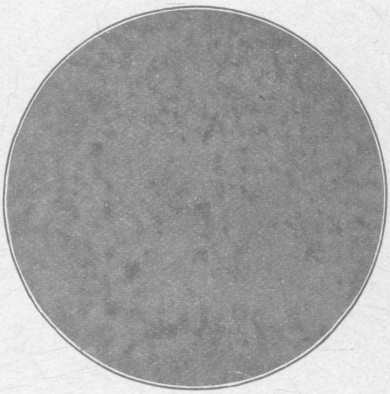

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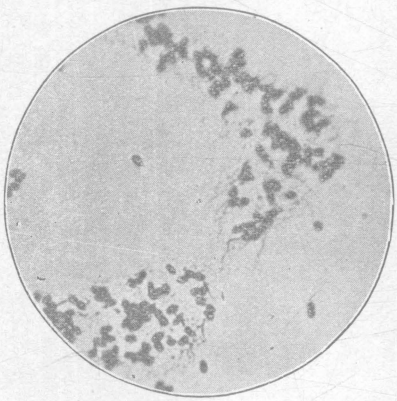

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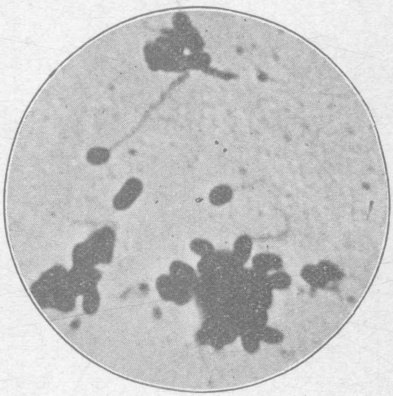

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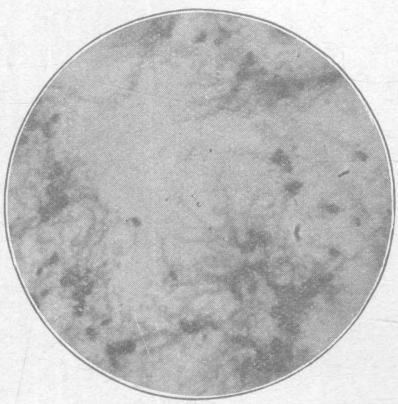

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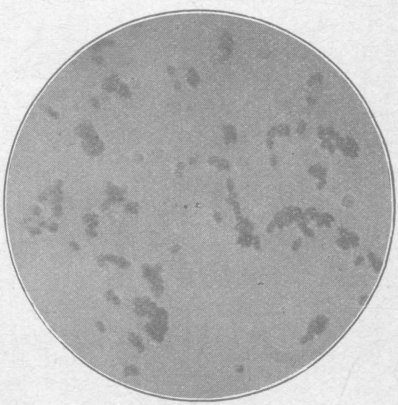

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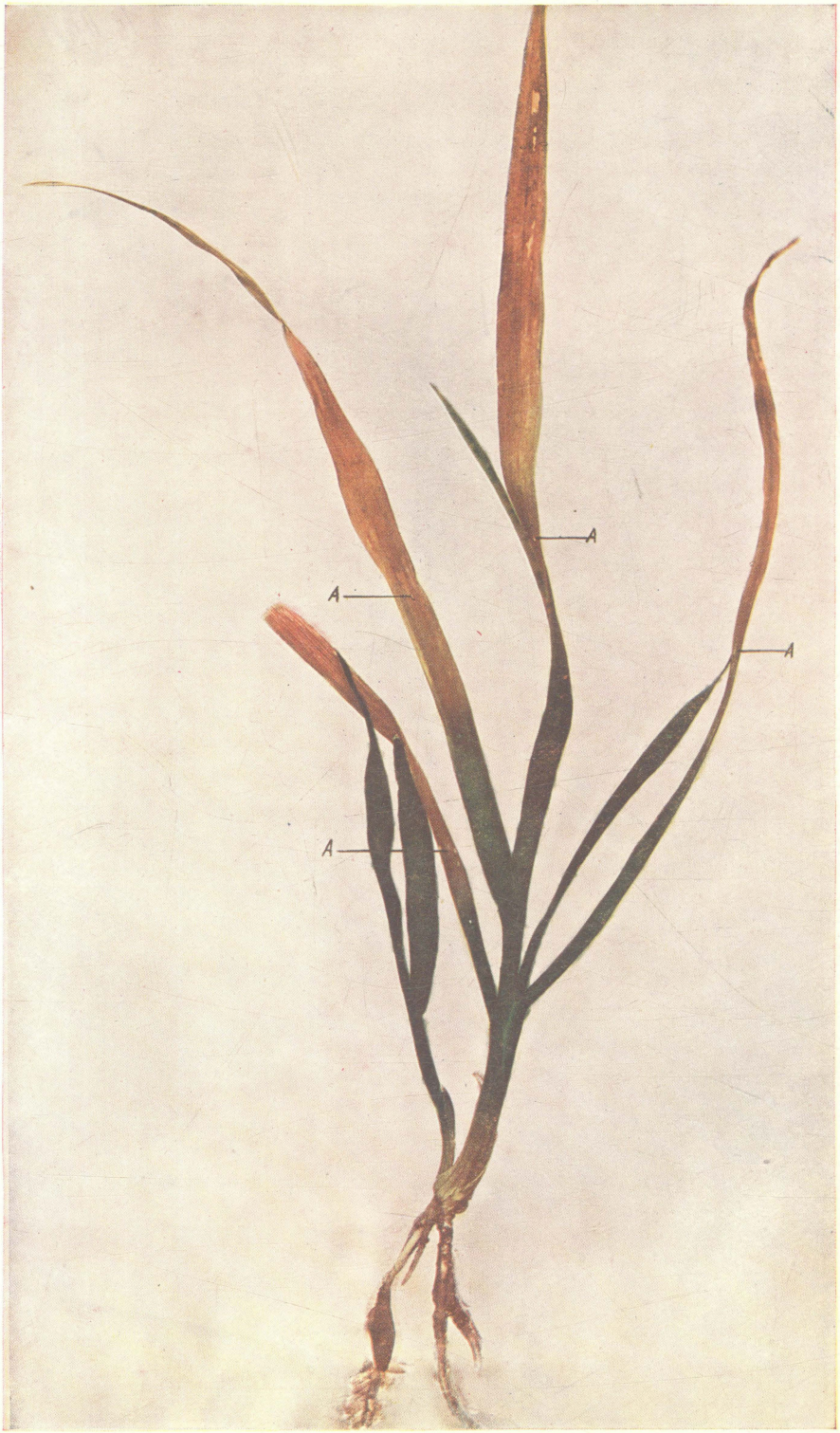
PLATE IX.

DESCRIPTION OF PLATE X.

Showing an oat plant infected with a mixture of artificial cultures of the bacteria (*Ps. avenae* n sp. and *B. avenae* n. sp.) which cause the brown blade blight of oats; inoculated by means of a hypodermic needle at the points marked "A." The preliminary results of the infection is a yellowing extending rapidly to the very tips of the leaves; should a day or so of hot sunshiny weather follow this yellowing, the leaves will quickly assume the characteristic reddish brown color typical of the bligh which results in an almost total collapse of the infected leaves. Infection had run two weeks at the time of photographing. Water colored. Natural size. 3-31-09. Original.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Agar stab. Growth best at top with an abundant growth at surface. Line of puncture filiform, slightly beaded; growth soon becomes yellow.

Gelatin stab: Growth best at top, filiform and somewhat beaded on upper line of puncture. No liquefaction takes place in four weeks. Growth turns yellow on the third day.

Nutrient bouillon: Medium becomes unevenly cloudy in twenty-four hours. The second day shows a heavy yellow precipitate.

Milk: Coagulation shows at the end of two weeks at which time extrusion of whey begins. The reaction of check was 1.57 percent acid to phenolphthalein. At the end of the second day's growth the reaction was 1.95 percent acid; at the end of the fourth day's growth the acidity was 2 percent. The general consistency of the milk remained apparently unchanged until the end of the second week, when coagulation set in.

Litmus milk: Shows acid at the end of the first day and gradually becomes more marked until the fourth week. Coagulation takes place the second week.

Gelatin colonies: Growth is very rapid; colonies visible in twenty-four hours. Round and slightly raised, edge entire; no pitting or liquefaction. Sub-colonies lenticular.

Agar colonies: Growth is rapid at room temperature; round, with smooth surface, slightly raised; edges entire. Amorphous somewhat denser at center. Sub-colonies lenticular, amorphous though center dense.

Growth: Growth takes place best on nutrient glucose or saccharose agar.

PHYSICAL AND BIOCHEMICAL FEATURES.

Gas and acid production: No gas is produced in the following bouillons: dextrose, saccharose, lactose, maltose and glycerin. Growth is noticeable in the arm of fermentation tube in the dextrose and saccharose, though not marked. There is possibly a slight growth in the closed arm in lactose and glycerin. The production of acid in each of the above media takes place as follows: Dextrose, check, 1.5 percent acid to phenolphthalein, first day's growth 3.8 percent, second day's growth 3.8 percent, fourth day's growth 3.8 percent. Saccharose, check, 1.9 percent, first day's growth 3.2 percent, second day's growth 3.5 percent, third day's growth 3.4 percent. Lactose, check, 1.7 percent, first day's growth 1.7 percent, second day's growth 1.9 percent, fourth day's growth 2 percent. Maltose, check, 1.8 percent, first day's growth 2.5 percent, second day's growth 3 percent, fourth day's growth 3 percent. Glycerin, check, 1.5 percent, first day's growth 1.9 percent, second day's growth 2.2 percent, fourth day's growth 2.2 percent.

Ammonia: No ammonia is produced in nutrient bouillon or in nutrient sugar bouillon.

Indol: Production of indol is moderate in sugar free bouillon.

Nitrate reduction: Nitrates are reduced to nitrites in nitrate broth.

Toleration of acids and alkalies: This organism makes fair growth in 2.5 percent acid medium to phenolphthalein while 1 percent alkaline medium retards its growth.

Optimum reaction for growth in nutrient sugar bouillon or nutrient sugar agar is +15 in Fuller's scale.

Vitality on culture media is long.

The thermal death point is reached in a ten minute exposure at 60° C. The optimum temperature for growth is between 20° and 30° C. Very resistant to exposure in light.

The organism is quite resistant to drying in cultures.

Effects of germicides: Killing results in ten minutes in a one in 10,000 solution of corrosive sublimate or in a one in 5,000 solution of formaldehyde. In a toleration test in nutrient glucose bouillon, growth failed in this medium having one gram of corrosive sublimate in 50,000 cc., and likewise when 1 cc. of formaldehyde in 10,000 was used.

Pathogenicity: The organism is not pathogenic by itself; however, in symbiotic relation with *Pseudomonas avenae* n. sp., it aids in producing the blade blight of oats.

THE POSSIBILITY OF SELECTING RESISTANT STRAINS OF OATS.

A casual examination of different oat varieties at the time when the disease is at its worst would seem to indicate little possibility of selecting a variety having much resistance. However, such a conclusion does not seem to be sustained when yields are considered. The results from the variety oat test at this Station for the season of 1907 (the heavy blight year) gave for the Sixty-Day variety a yield of 56.95 bushels as compared with 54.49, 51.13, 50.63 bushels for the three next higher yielding varieties and with 44.75 bushels for the average of all varieties excluding the Sixty-Day. Van Hook in his correspondence (see p. 100) notes that there existed differences in resistance to the blight disease in the oat varieties being compared here in 1907.

In 1908, the outbreak at this Station was at first most severe among the earliest sowings (some sowings of the early and late test) which were located at the south of the tier including the variety tests. Later, however, the disease appeared to be somewhat general, though not severe, on most of the varieties, appearing to be somewhat more pronounced upon Wideawake.

In the infection work in the pathologium from February to May, 1909, two varieties, viz., Improved American and Wideawake, were used respectively in the different inoculations, and it was quite

noticeable that Improved American was slower on an average to show infection than was Wideawake. Again it was noticeable that a few individuals showed marked difference in resistance from the average. It is from these individuals rather than from any special variety that the writer believes the more valuable resistant selections may come. On the other hand, there is little doubt but that the variety which shows the most resistance will also offer the greatest number of individuals for selection. Observations made this season (1909) indicate that there is some difference in susceptibility to the blight disease as manifested by the amount of infection showing on the different varieties in the test plots at the Station. The strain selected and grown as a winter oat showed no sign of blight this season, as far as the writer could determine. This same strain, when sown as a spring oat, showed but the slightest trace of the disease. On the other hand, Wideawake and several of the other varieties showed a marked beginning of infection at one time. The disease made little or no headway after the advent of sunshiny, dry weather, thus preventing further observations on the spread of the disease, and the resistance of varieties. The writer is fully satisfied that there is a good opportunity for selecting resistant strains which would quite easily overcome much of the losses from this disease.

The following data show the yields of Improved American compared with Wideawake and the average of all varieties grown in the variety oat test at this Station during the past six years[21].

	1904	1905	1906	1907	1908	†1909
Improved American.....	85.66	59.45	87.21	45.47	67.18	73.51
Wideawake.....	77.26	56.65	73.02	40.20	50.19	55.42
Average of all varieties...	77.75	59.16	77.90	45.25	62.02	65.81

In each of the above years it is apparent that the Improved American variety outyielded Wideawake considerably, also that the average of all varieties exceeds Wideawake in yield. Some of this difference in yield between other varieties and the Wideawake is undoubtedly due to the latter's non-resistance to the blight disease.

BREEDING OF RESISTANT STRAINS AN IMPORTANT PHASE OF EXPERIMENT STATION WORK.

The writer is an ardent believer in the "ounce of prevention" theory. There are, however, two ways in which the agriculturist may considerably ward off plant diseases; one is to be continually on the alert and apply proper treatment at the right time. Should he, however, be trying to grow varieties which are very susceptible to disease, this method is not always the most pleasant and most practical.

[21] Cir. 88, Ohio Agric. Exp't. Sta., Feb. 15, 1909, C. G. Williams.

†From data of 1909 yields furnished by C. G. Williams.

DESCRIPTION OF PLATE XI.

Showing the oat blight resulting from aphides carrying the disease. The two leaves at the left came from the check row, which became infected through the grain lice carrying the disease from the infected row. (See Plate II and the description). The lice were placed on the infected plants of the inoculated row; both rows were then caged in; in two weeks these insects had carried the disease to the check (healthy) row with the bacterial blight resulting as photographed in the two leaves at the left The leaf at the right came from the cage in which the aphides free from the bacterial blight disease were confined (see Plate III and the description). The injuries resulting to oats from the sucking of aphides is entirely different from the blade blight. (See Plate IV). 3-31-09. Original. Natural size

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A second means is to secure varieties which are known to be very resistant to the more common diseases. To accomplish the end in view both of these means: resistant varieties and treatment, should be diligently looked after. The value of using resistant varieties or strains is everywhere apparent. Take for example the loose smut of wheat in this state. Observations and examinations show that this disease is causing losses in different fields from less than .01 percent to as high as 5 percent. That such a heavy loss as 5 percent or even 2 percent is simply a matter of unwisely continuing the use of a susceptible variety is very evident. During the season of 1908, the varieties of wheat grown at this Station were carefully counted to estimate the percent of loose smut. Only seven varieties out of some forty-seven showed a loss of over 1 percent due to this disease. Among these seven are to be noted the following: Pride of Genesee 1.08 percent, Prosperity 6.47 percent, American Bronze 5.14 percent, Invincible 5.20 percent, Hickman 1.02 percent, Golden Bronze 1.87 percent, and Dawson's Golden Chaff 1.75 percent. Of the remaining forty varieties, thirty showed less than .5 percent loss from loose smut, and of these thirty, fifteen showed .05 percent or less; five showing practically no loose smut. Among those that show little or no loose smut were some of the best yielders. It is observed that these susceptible varieties show more or less smut every season. During 1908 the writer attempted to infect with loose smut the variety of wheat known as Poole. The result was negative owing to this variety's resistant qualities to the smut disease. The same is true also of oats, barley, flax, potatoes and many other crops in relation to their specific fungous diseases. Some have considerable resistance to plant diseases, possessing also good quality and high yielding capacity.

The time is now ripe when systematic selection of strains from different varieties for resistance to prevalent plant diseases may be made a great economic factor in modern production. The question so often raised, why not let nature have her course and we continually select the most prolific among the survivals, is answered by the remark that nature is much too slow for our generation, also the layman not having the knowledge of conditions favoring and limiting plant diseases, is not in line to control nature; when nature does afford the opportunity he is too deeply concerned in other lines to take advantage of it. Diseases are periodic, that is, they make their appearances irregularly according to whether meteorological conditions are favorable or not; along with favorable conditions must be present not only particular means of infection, that is, the spores or other propagating parts of the disease, but also the host. If nature were regular in her seasons, and similar in her corresponding periods, then the matter of breeding for resistant strains would

be simplified. At present, however, to accomplish ends too difficult for the layman, requires the training of the pathologist. That is, the pathologist having the specific infecting material at hand and knowing the necessary environment for the development of the disease, may and can maintain these, and subject the plant to such each year, instead of waiting for those years having the periodical outbreak of the required disease. The meteorological requirements of certain diseases are now so well known that it is quite possible to keep these diseases active in unfavorable seasons, simply by supplying the necessary conditions. This was readily shown in working with the oat blight in the pathologium during the past winter. Conditions which were unfavorable for the development of the disease were overcome by maintaining a partial shading and a saturated atmosphere.

SOME OF THE NEEDS AND POSSIBILITIES OF SELECTION FOR DISEASE RESISTANT PLANTS.

Work under glass: That the pathologium or properly regulated greenhouse can be of great use in the preliminary testing and selection of resistant strains is very evident to the writer, he having previously made use of such means in testing flax as to its resistant qualities to the flax wilt disease*. For special work of this kind, however, a greenhouse is required with apartments which permit of auto-regulation in ventilation, heating, lighting and moisture. A system which permits such regulation in heating and ventilation is not difficult to install. Likewise moisture conditions may be more or less easily controlled. Even lighting permits partial control. The great advantage of such greenhouse work is evident when with certain plants we can make time in multiplying individuals by growing and maturing an extra crop during the winter, permitting inoculation under favorable conditions for disease production, thus readily distinguishing resistant from non-resistant individuals. Such conveniences would not only give opportunity for preliminary selection, but also the means for testing out supposed resistant individuals, which under field conditions may strike the proper conditions for a test but once in two to five years. Where we start from individual plants and have no further means than nature to bring about proper meteorological conditions for the disease, sometimes we are much disappointed after carrying a good yielding plant several years, to find that it succumbs upon the appearance of certain fungous or bacterial diseases.

* "Fungi of Flax-sick Soil and Flax Seed," 1902-1904. Submitted to the North Dakota Agricultural College, Department of Botany, Feb. 1,1909, for publication.

SOME OF THE LINES ALONG WHICH FURTHER STUDY SHOULD BE MADE ON THE OAT BLIGHT.

The writer is fully convinced that this bacterial blight is the means of bringing about an abnormal condition of the oat crop throughout the eastern and central states. The observations and investigations herein recorded cover but a few phases in the study of this very general and important trouble.

Some suggestions pointing to investigations which would further make clear the relation between the oat blight and the specific organisms which are the cause of this disease, and economic means for the control would not be out of place at this time. Among the more important questions to be settled are the following:

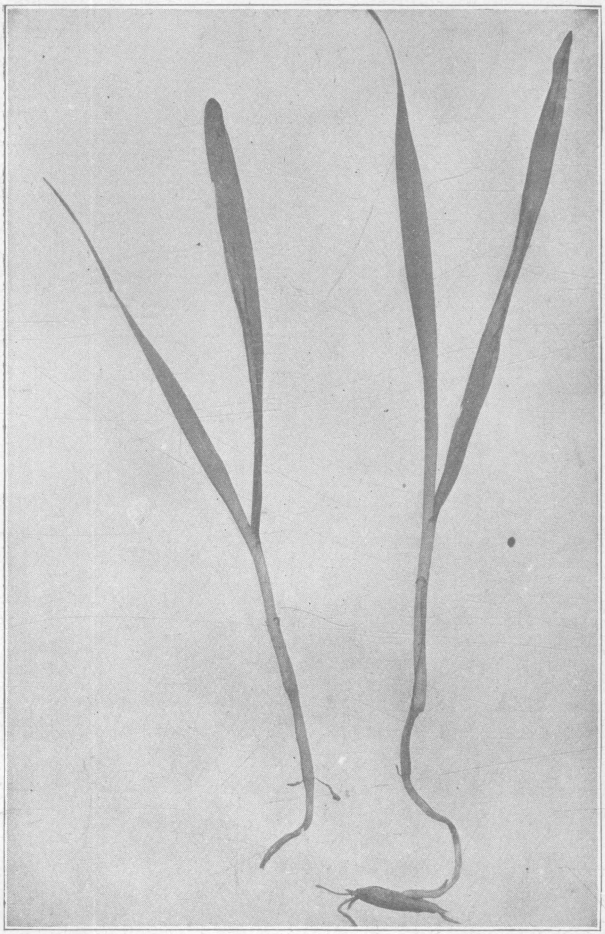
1. Are these specific oat blight organisms common and persistent in soils?
2. If so, do they give rise within the soil to products which are injurious to oats and other crops?
3. If so, are these products easily or difficultly destroyed?
4. To what extent are these blight organisms within the soil responsible for the weakened vitality so conspicuous in oats?
5. What relation exists between blight and blast in oats?
6. In what types of soil and under what meteorological conditions do these blight organisms thrive best?
7. Can this blight trouble be overcome by the selection and breeding of resistant varieties?

DESCRIPTION OF PLATE XII.

1. Showing oat seedlings affected with the Helminthosporium blight. On some of the variety plots of the Experiment Station the affected plants reached 16 percent. The plants, as a rule, quickly outgrow this blight. Enlarged one and one-eighth times. 5-10-09.

2. Showing nutrient glucose agar plate culture of pieces of oat blades infected with the Helminthosporium blight. Observe the fungus coming from the pieces of oats. The soil upon which these oats grew was treated very heavily with a solution of 1 pound of formaldehyde to 20 gallons of water, using one gallon per square foot. The oats were also thoroughly treated with a solution of formaldehyde made with 1 pound to 40 gallons. These treatments either failed to kill the fungus in the soil or on the surface of the seed, or the fungus is internal. Following the above treatment on the variety. Improved American, 9 percent of the seedlings showed infection with this blight. The Wideawake variety showed nearly 11 percent of the seedlings infected. 2-26-09.

3. Showing the under surface of nutrient glucose agar plate cultures of the Helminthosporium fungus coming from pieces of infected oat blades. The sub-medium growth of this fungus assumes a very dark color as illustrated. The aerial mycelium, however, has a gray color. Plates by one-half 3-15-09. All original.



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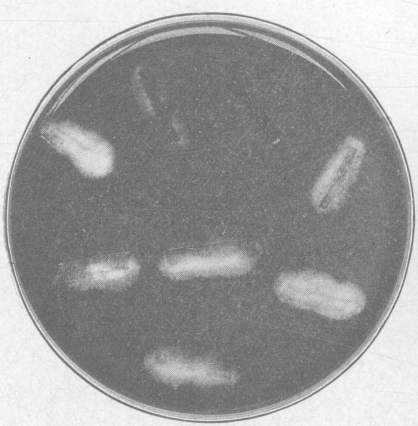

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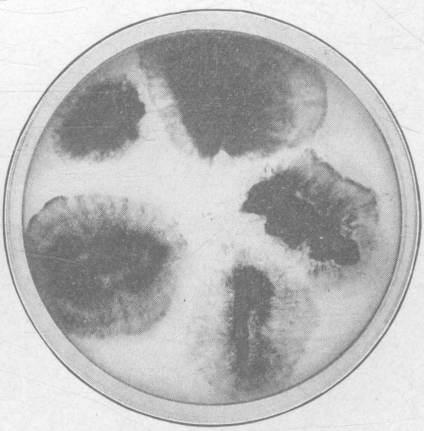

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PLATE XII.

DESCRIPTION OF PLATE XIII.

Showing a photograph of three oat blades in different stages of the bacterial blight (from natural infection) which has in no way been complicated with the work of aphides.

1. Showing preliminary lesions (the larger, light, oval spots) from stomatic infection, spread by rains The smaller dark spots are caused by a fungus, *Helminthosporium avenae sativae* (*Briosi* and *Cavara*).

2. Showing a general yellowing of the blade due to primary stomatic infection on the stem.

3. Showing partial breakdown of a leaf due to the blight lesions becoming confluent.

NOTE: Illustrations in this plate show separate and distinct lesions. When infection is generally distributed the lesions quickly become confluent, giving the blades a mottled yellowish brown appearance.

(All from the oat variety plots, Ohio Agricultural Experiment Station, Wooster, June 15, 1909).

6-15-09. Original. Enlarged one and one-third times.

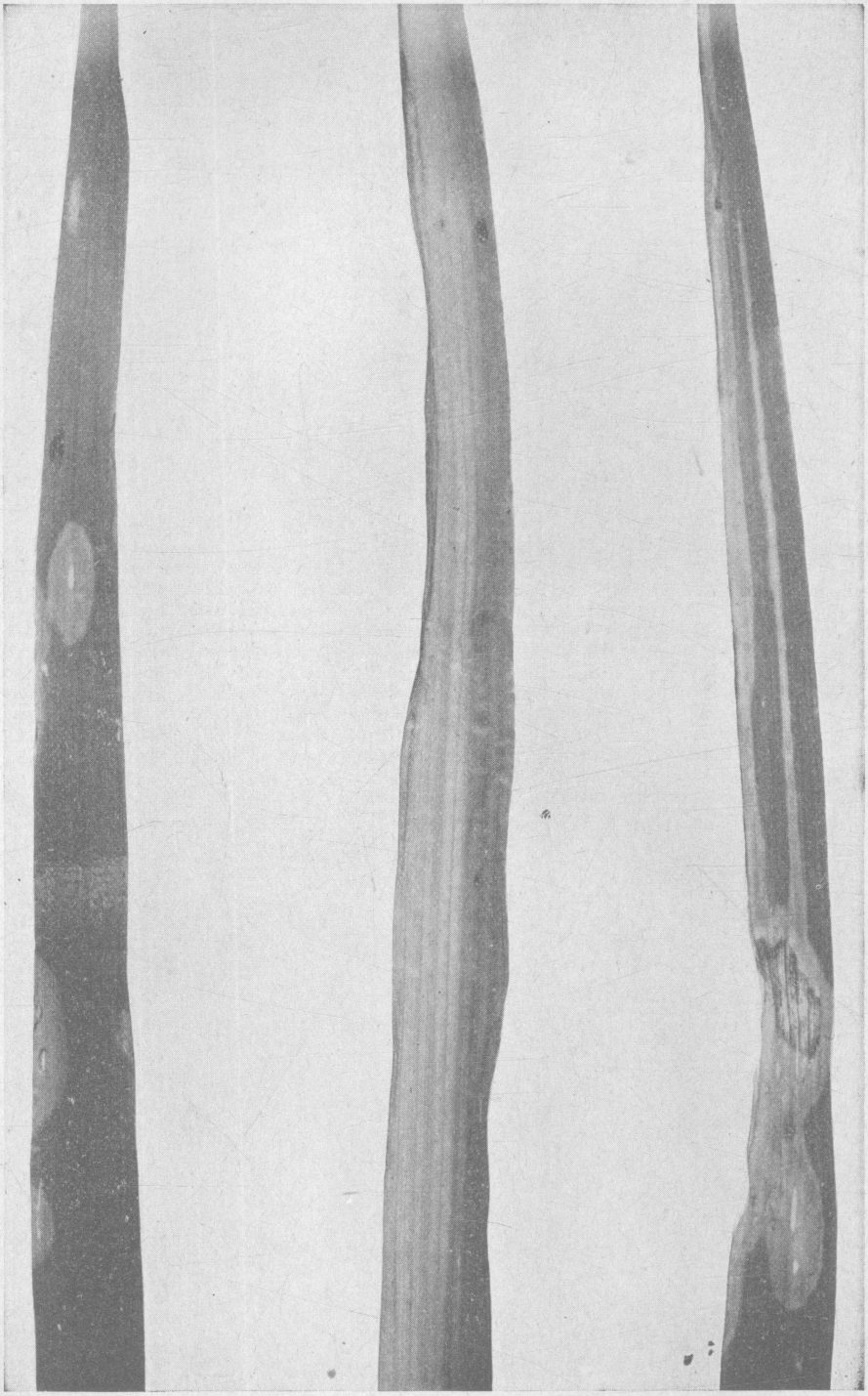

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PLATE XIII.

DESCRIPTION OF PLATE XIV.

Showing the "blast" of oats resulting from the bacterial blight disease (natural infection). In this case the flag leaf had completely collapsed, and the lesion had passed downward attacking and blasting the head. In many cases the panicle was completely killed before it had emerged from the sheath. The small light spots on the lower leaf in the illustration, are beginning lesions of the bacterial blight. This shows the disease resulting from stomatic infection by spattering of rain. The oat plants at this stage were about three feet high; many showed partial collapse due to infection of the lower leaves and culms; by two-thirds.

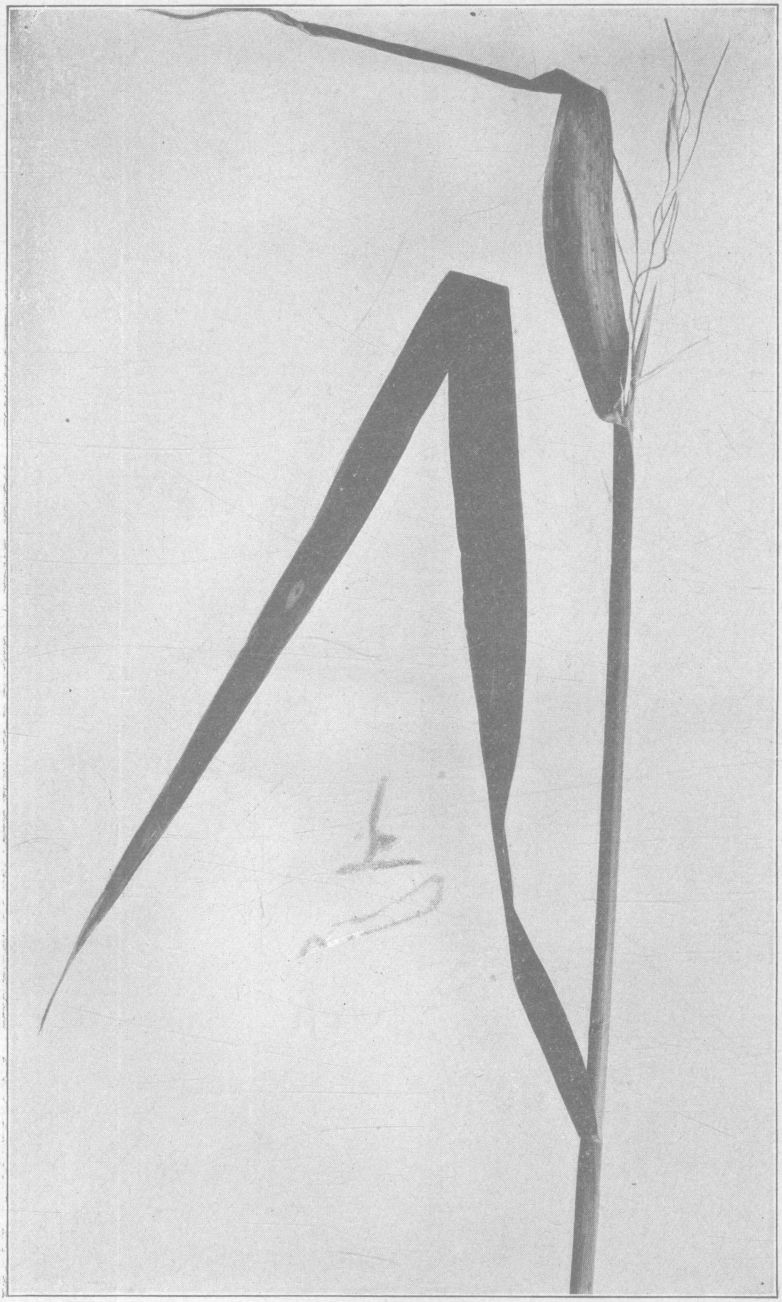

PLATE XIV.

DESCRIPTION OF PLATE XV.

Showing in Fig. 1 the aphis eggs found so common on apple twigs in 1908 and 1909. The writer gathered a number of these twigs (see p. 117) from different sources, and bred out the insects, in an attempt to secure *Macrosiphum granaria* or *Syphocoryne avenae* to learn whether these carried the bacteria of oat blight, to and from the apple. Upon being hatched these aphides failed to live upon the oats at all, even after several generations had been produced upon the apple, indicating that the eggs so plentiful on apple twigs in 1908 and 1909, were undoubtedly those of *Aphis mali*, the apple aphis

Showing in Fig. 2, the first generation of aphides on the buds several days after hatching from the eggs.

Showing in Fig. 3, later generations of the aphides at work on the apple leaves. The above illustrations are from work carried out in the pathologium. All enlarged two diameters. 3-3-09 and 5-6-09.

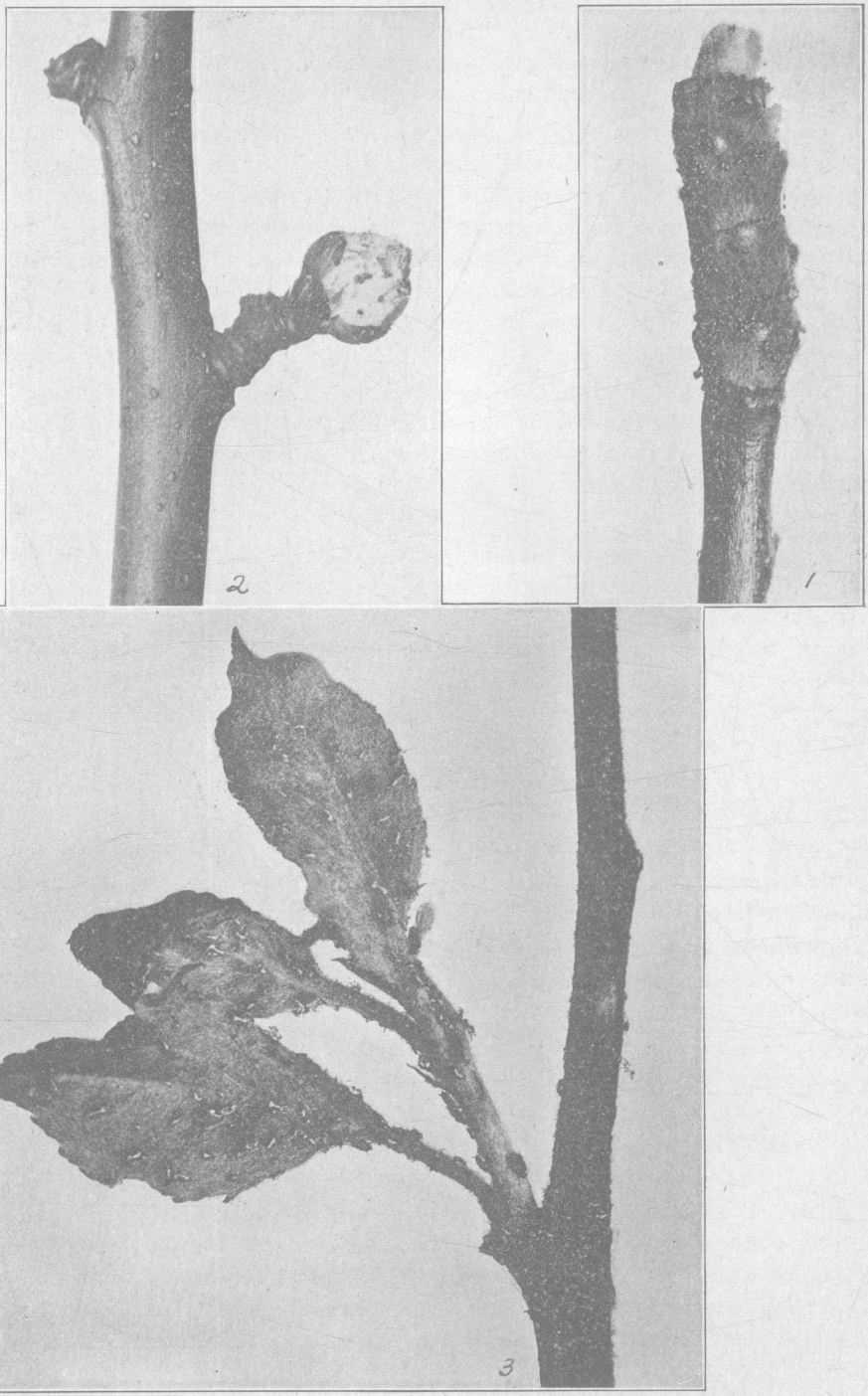

PLATE XV.

SUMMARY.

1. There is prevailing throughout the oat area of the central and eastern states an abnormal condition of the oat crop.

2. Many reasons have been assigned by different writers as the cause of this condition, among which have been mentioned, physiological, resulting from the cold, wet, cloudy seasons; again, insects have been held responsible; in several instances a specific bacterial disease has been assigned as the cause. The difficulty of distinguishing the bacterial blight from other similarly appearing, but more limited troubles, has given rise to much difference of opinion as to the cause.

3. The writer finds that a specific bacterial disease is the chief factor in bringing about this abnormal condition of the oat crop.

4. This disease results from a symbiotic relation of two bacteria. Their activity is greatly favored by rainy, humid and cloudy weather.

5. The disease in its severity is chiefly confined to oats, although a somewhat similar disease has been observed to a less extent on timothy and bluegrass, and, on each of a susceptible variety of wheat and barley recently brought to the Experiment Station, for trial. In the observations on timothy and bluegrass it is to be noted that the foliage suffers but little, while the culm is killed above the upper joint.

6. The chief method of infection is through the stomata, the organisms being spattered on the leaves from the soil by rains. A secondary means of dissemination is the work of grain insects.

7. In Ohio the seasons of 1907, 1908 and 1909 have been quite favorable to the development and spread of this disease. Probably the greatest outbreak of this disease occurred in 1890, when it was observed from the Atlantic Coast to as far west as Indiana, and from the Great Lakes to the Gulf States.

8. The yields of oats in Ohio in 1890, 1907 and 1908, the three years when this blight was excessive, were reduced respectively, 36.7 percent, 24.3 percent and 14.4 percent below the average for the past eighteen years.

9. The preliminary effects of this disease is a yellowing, beginning either as small, round lesions on the blade, or as long, streak lesions extending throughout the blade or even the whole length of the culm and blades. Occasionally it begins at the tips and works back into the culm; again the upper leaves often break down through a weakened condition of the plant from defoliation below.

10. The ultimate symptoms wherever the disease has made much progress, are partial or general collapse of the leaves, due either to active lesions within the blades, or to a weakened vitality of the plant; this weakness results directly from impairment of foliage, or sickness of culm and roots. In the advanced stages the affected blades take on a mottled to almost red color, which has been called "rust," "blight," and emphasized by the expression "as red as fire."

11. It seems probable that where the soil has become filled with these specific organisms, it has become partially "oatsick." Apparent "oatsick" areas have been observed by the writer and he attributes these conditions to the bacterial blight organisms.

12. Observations indicate that the "blast" of oats is more or less directly proportional in amount to the severity of the blight disease. In some instances "blast" is directly due to active lesions of the blight killing the parts of the panicle infected. As a rule, however, it appears that "blast" results from an impaired vitality, occasioned several weeks previous to the emerging of the panicle. Heads examined one to two weeks previous to the time for their appearance showed "blasted" kernels, and the amount of "blast" was apparently proportional to the amount of blight, or in other words, to the amount of impaired vitality.

13. Some variation in the amount of blight is observed in different areas on every infected field; these irregularities are little influenced by fertility or drainage.

14. The writer has studied the morphological, cultural, physical and biochemical features of these two specific bacteria, and finding they differ from previously described organisms*, they have been named *Pseudomonas avenae* n. sp. and *Bacillus avenae* n. sp.

15. The difficulty met with in diseases which are more or less soil troubles, that is, diseases which may be carried for several years in soil without the presence of their particular hosts, have best been overcome by breeding and selecting resistant strains.

16. From observations gained through artifical inoculations and from conditions as they appear in field crops, and upon the different varieties of oats, it seems to the writer, that there is a good opportunity for selecting resistant strains.

ACKNOWLEDGEMENTS.

The writer desires to express his appreciation to those who have helped in gathering material and data for this publication; to Messrs. Rankin, Behoteguy and Goheen, for their assistance in laboratory and photographic work. The writer is especially indebted to Prof. A. D. Selby for his kindly suggestions and readiness in furthering the investigations.

* The writer reviewed the systematic works of Migula and Chester. See references (23) and (24) in literature cited.

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